United States
Department of
Agriculture

Economic Research Service
Forest Service
Soil Conservation Service
and
Cooperating Agencies
Vermont

AGRICULTURAL RUNOFF IN SELECTED VERMONT WATERSHEDS

Main Report of the
Agricultural Runoff in Selected
Vermont Watersheds Study

February 1983

245 00 AGRICULTURAL RUNOFF IN SELECTED VERMONT WATERSHEDS : +b

Main Report,

Agricultural Runoff in Selected Vermont Watersheds Study / +c

U.S. Department of Agriculture,

Economic Research Service,
Forest Service,
Soil Conservation Service ;

In cooperation with

State of Vermont,
Agency of Environmental Conservation,
Department of Agriculture.

Soil Conservation Service
One Burlington Square, Suite 205
Burlington, VT 05401

February 1983

ABSTRACT

This report provides evaluations of the existing and future condition of agricultural and forest land runoff in nineteen Vermont watersheds. These heavily agricultural watersheds drain to lakes and ponds of primary concern to Vermonters for control of accelerated eutrophication.

The report briefly examines the existing and projected land, water, social, and economic resources of the study area. It reviews the aging process, or eutrophication, of all or portions of the receiving lakes and ponds. It covers particular problems and concerns within each of these water quality management areas.

Total phosphorus is the limiting nutrient to eutrophication and is summarized by major point and nonpoint sources to each of the water quality management areas. The significance of agricultural and forest land contributions is readily apparent. The major agricultural nonpoint sources of phosphorus are cropland soil erosion, inadequate manure storage and utilization, and barnyard and milkhouse runoff. The major forest land source is excessively eroding harvest roads.

In finding solutions to agricultural runoff problems, an array of alternatives are compared. These are evaluated in terms of their effectiveness in: (1) reducing phosphorus losses; (2) controlling erosion and sediment; (3) minimizing overall cost of runoff control; and (4) minimizing farm costs in the control process.

A suggested plan and its effects are provided. The watersheds are also ordered in a suggested ranking for implementation of nonpoint source control measures.

The main report closes with a review of management programs available and a proposed schedule for the work.

Several technical reports have been published as a part of the study. The "Readers Guide to the Report" in Chapter 1 provides further information.

TABLE OF CONTENTS

PAGE NO.

CHAPTER 4 CLEAN WATER THREATS FROM LAND RUNOFF

CHAPTER 5 FINDING SOLUTIONS TO LAND RUNOFF PROBLEMS

LIST OF TABLES

LIST OF TABLES, continued

LIST OF TABLES, continued

LIST OF TABLES, continued

LIST OF FIGURES

LIST OF MAPS

CHAPTER 1

A STUDY OF LAND RUNOFF IN VERMONT

BACKGROUND

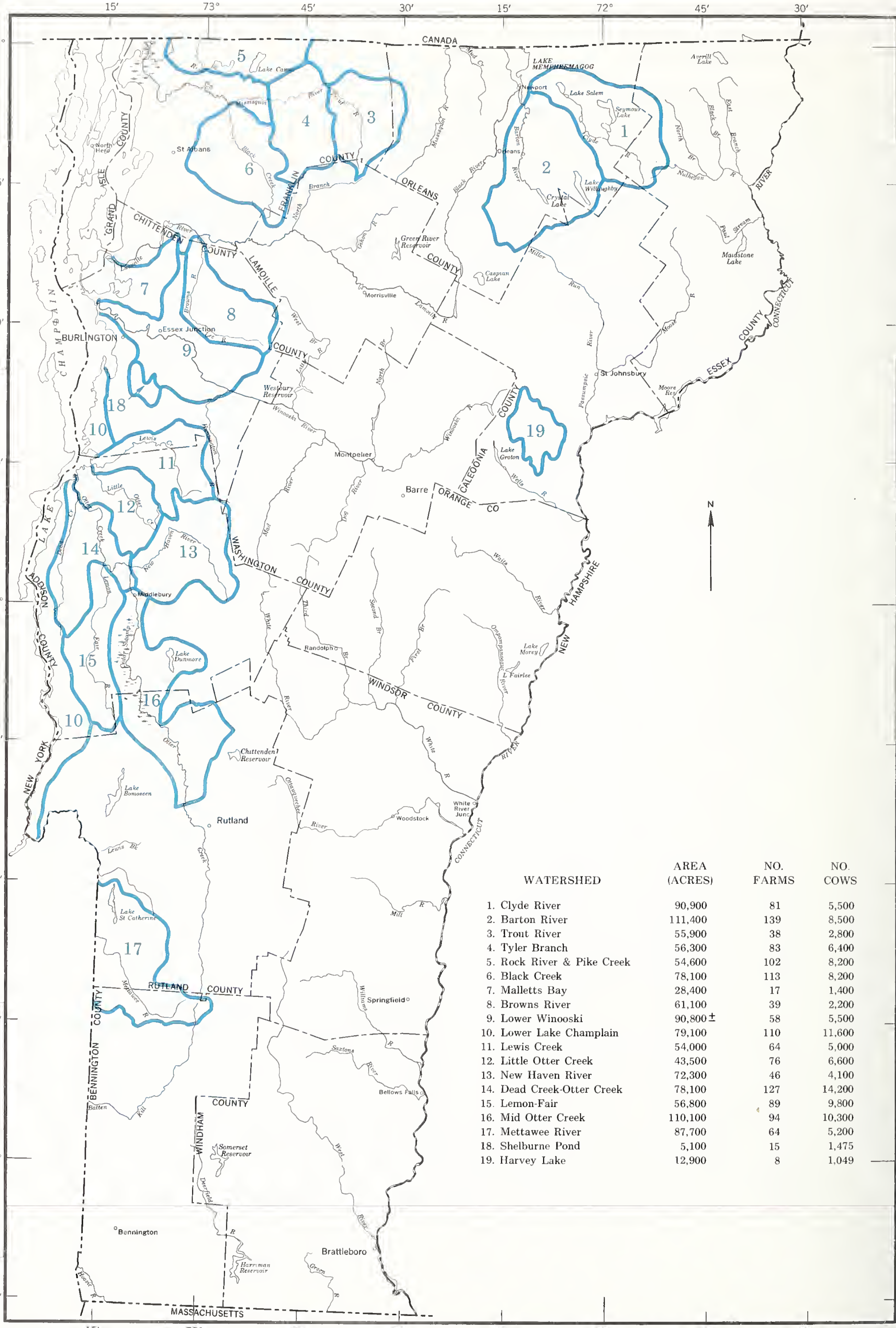
Concern for water quality in Vermont has focused on the effects of water pollution on the principal lakes draining the State: Lake Champlain and Lake Memphremagog. While ambient water quality in tributary streams is generally good, continued delivery of nutrients, organic material and sediment from point and nonpoint sources is contributing to accelerating eutrophication in the lakes. The Lake Champlain Level B River Basin study found that 52 percent of annual phosphorus loads, the limiting nutrient for most nuisance aquatic plants, were from nonpoint sources. Agricultural land is the largest nonpoint source of phosphorus.

The State of Vermont prepared a plan for controlling agricultural pollution as a segment of the State Water Quality Management Plan, as required by U.S. Environmental Protection Agency regulations 40 CFR 130 and 131.11. The plan evaluates the nonpoint source pollution problems from agriculture, prioritizes major watersheds for Rural Clean Water Program (RCWP) funding, and discusses options available to control nonpoint source pollution. The plan is not in sufficient detail to support applications for RCWP, small watershed projects under PL-83-566, or other special water quality projects, nor does it establish priorities between small watershed areas.

The purpose of this study is to refine watershed priorities and estimate need for and effects of erosion, sediment, and animal waste control practices. The study will provide an information base so that state and local sponsoring agencies can properly develop applications for water quality protection projects.

The area pertinent to this study consists of seventeen watersheds in the principal drainages to Lake Champlain and Lake Memphremagog. In addition, smaller lake drainages around Shelburne Pond and Harvey's Lake have been included for study. These watersheds, shown in Map 1.1, lie mainly in Addison, Chittenden, Franklin, Orleans, and Rutland Counties which constitute the most important agricultural areas of the State. The LaPlatte and St. Albans Bay drainages are the only watersheds from the State plan not included in the study area since they have been studied under other previous efforts.

The effort is a joint Federal-State cooperative river basin study, authorized under Section 6 of PL-83-566 passed in August 1954. It was requested by the Vermont Agency of Environmental Conservation (AEC) in a letter dated July 13, 1978. The Chief, Soil Conservation Service (SCS), USDA, authorized the State Conservationist to collaborate with AEC and other USDA agencies in developing a plan of work for the study in August 1978. The plan was approved and work commenced in March 1979. Participating agencies include Vermont AEC as sponsor, SCS as lead Federal agency, the Economic Research Service (ERS) of USDA, and the Forest Service (FS) of USDA. Numerous other State,



WATERSHED	AREA (ACRES)	NO. FARMS	NO. COWS
1. Clyde River	90,900	81	5,500
2. Barton River	111,400	139	8,500
3. Trout River	55,900	38	2,800
4. Tyler Branch	56,300	83	6,400
5. Rock River & Pike Creek	54,600	102	8,200
6. Black Creek	78,100	113	8,200
7. Malletts Bay	28,400	17	1,400
8. Browns River	61,100	39	2,200
9. Lower Winooski	90,800±	58	5,500
10. Lower Lake Champlain	79,100	110	11,600
11. Lewis Creek	54,000	64	5,000
12. Little Otter Creek	43,500	76	6,600
13. New Haven River	72,300	46	4,100
14. Dead Creek-Otter Creek	78,100	127	14,200
15. Lemon-Fair	56,800	89	9,800
16. Mid Otter Creek	110,100	94	10,300
17. Mettawee River	87,700	64	5,200
18. Shelburne Pond	5,100	15	1,475
19. Harvey Lake	12,900	8	1,049

Source Data: U.S. Geological Survey 1:500,000 Base Map

USDA-SCS-LANHAM, MD. 1982

Federal, and local governmental agencies, organizations, and individuals cooperated with the study.

READER'S GUIDE TO THE REPORT

The main body of this report is divided into seven sections. In addition, there are five technical reports prepared during the study which are referenced in this report and are available separately.

The Vermont Scene provides physical and socio-economic background material about the study area that is useful to put the report findings in perspective. The Aging of Vermont Lakes describes the process of accelerated eutrophication brought on by human activities which is polluting the lakes under study and presents water quality data documenting the extent of the process to date. Clean Water Threats from Land Runoff summarizes the sources of lake pollutants and discusses the role of agricultural and silvicultural activities as sources of pollutants. Finding Solutions to Land Runoff Problems describes the analyses conducted as part of the study, the planning process undertaken, and the resulting plans developed. The Suggested Plan and Its Offsite Effects describes the relationships between watersheds examined in the study and the lake areas which they impact and lays out the plan suggested by the study results. The probable effects of implementing the plan on pollutant loadings and on the agricultural sector are examined. Finally, Getting on With the Job defines the major programs needed to implement the plan, the agencies responsible for implementation, and the role of the public in moving Vermont toward cleaner waters.

The appendices to this report contain detailed information in support of the text and are arranged in the same order as the chapters. A glossary provides definitions of unfamiliar terms, technical terms, and terms used with a particular meaning in this report. A list of references completes the document.

Five separate technical reports are available which provide detailed documentation of methods used in the study. These are:

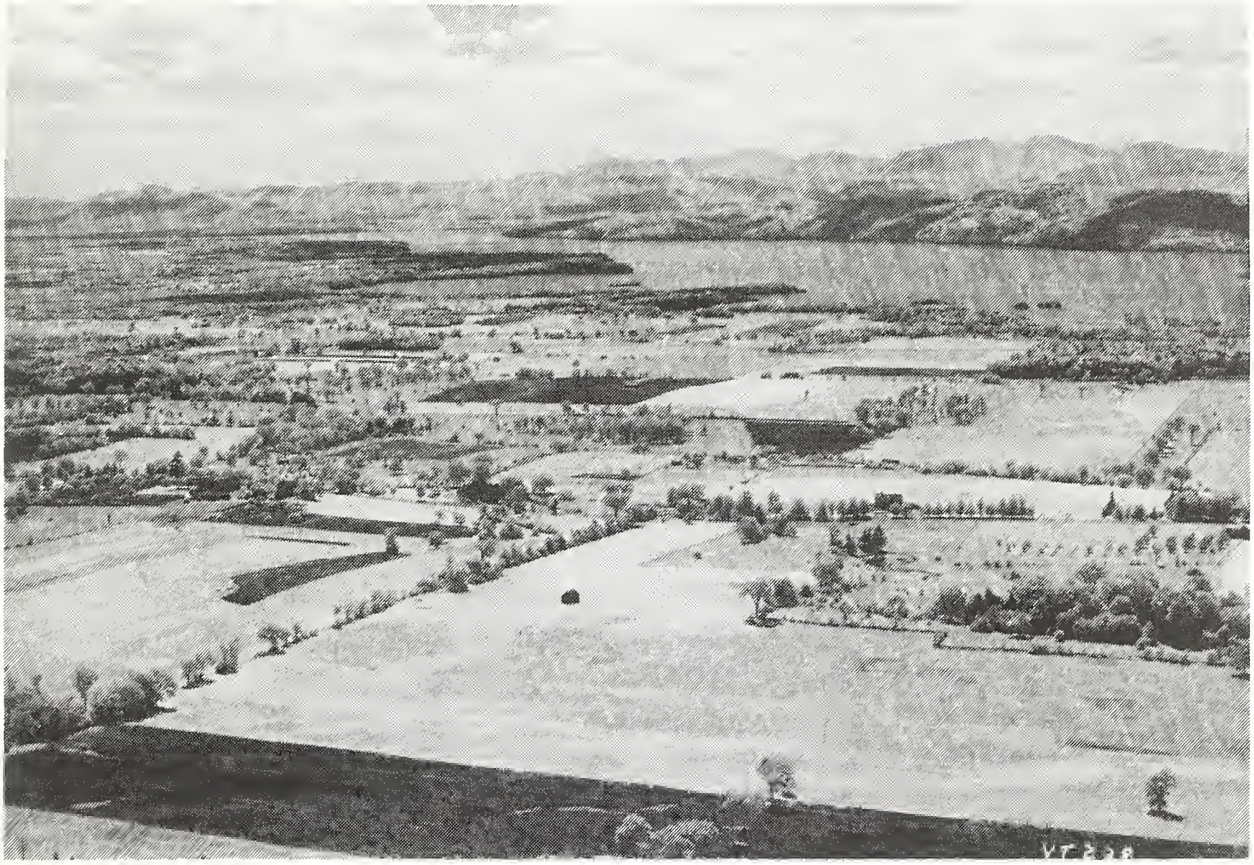
Soil Conservation Service. Computational Methods for Assessing Phosphorus Losses in the Vermont Agricultural Runoff Study. Vermont Ag. Runoff Technical Report No. 1, Soil Conservation Service, USDA, Burlington, Vermont, May 1982.

Heimlich, R.E. Phosphorus Reduction and Farm Income: Modeling Efficient Responses to Phosphorus Loading Constraints on Vermont Dairy Farms. Vermont Ag. Runoff Technical Report No. 2, Economic Research Service, USDA, Burlington, Vermont, May 1982.

Forest Service. Erosion and Sediment Production from Logging Roads in Vermont. Vermont Ag. Runoff Technical Report No. 3, Forest Service, USDA, Burlington, Vermont, September 1981.

Forest Service. Proposed Private Road System in the Browns River Watershed. Vermont Ag. Runoff Technical Report No. 4, Forest Service, USDA, Burlington, Vermont, September 1981.

Soil Conservation Service. Quantification of Resources and Problems in Vermont Agricultural Runoff Study Watersheds. Vermont Ag. Runoff Technical Report No. 5, Soil Conservation Service, USDA, Burlington, Vermont, October 1982.



CHAPTER 2

THE VERMONT SCENE

PHYSICAL SETTING

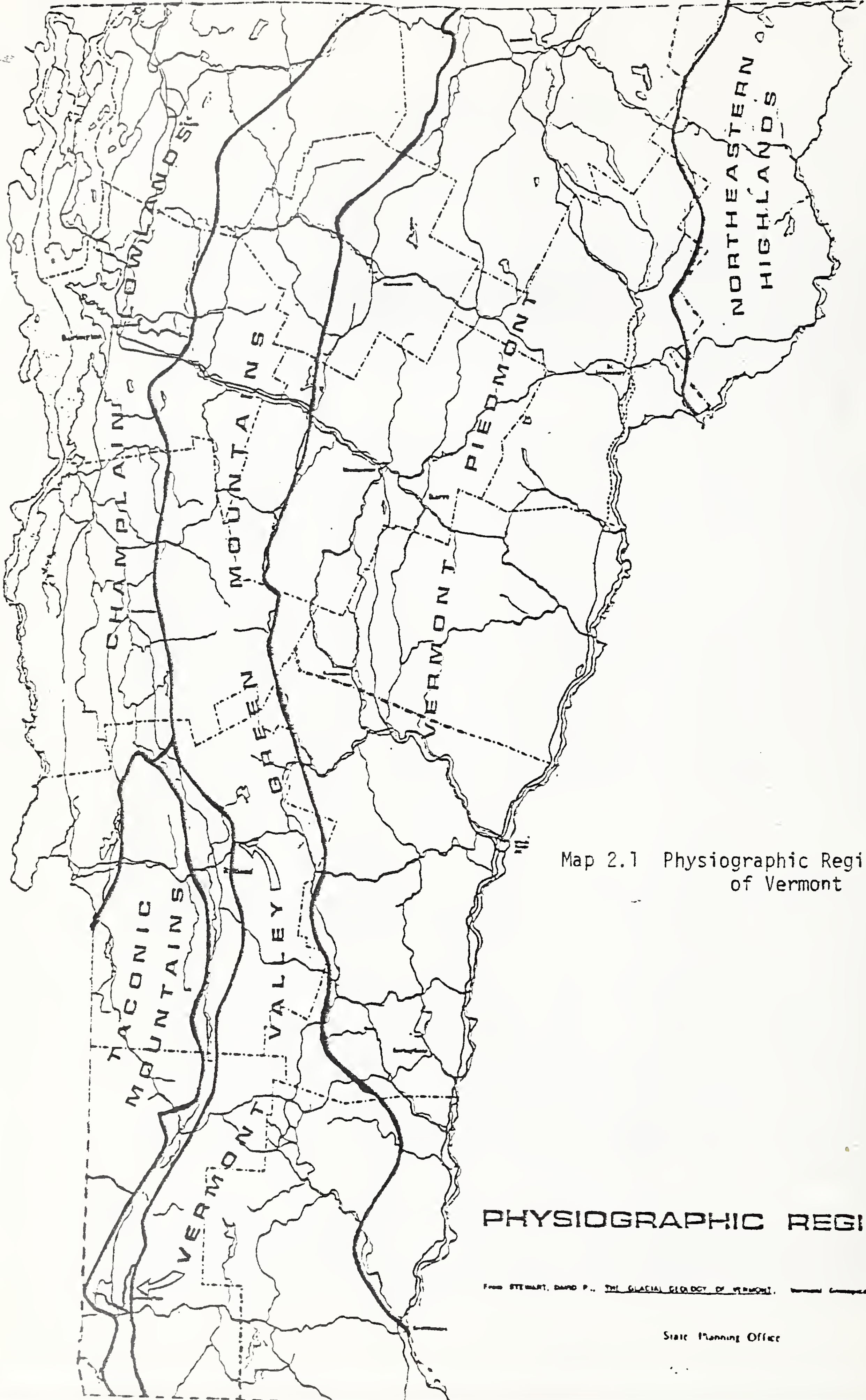
Land Resources

Vermont contains a wide variety of visual and physiographic diversity. The State is commonly divided into six physiographic regions (see Map 2.1) each with its own distinctive geology, climate, and vegetation (Meeks, 1975). The regions are: the Champlain Lowlands, Taconic Mountains, Vermont Valley, Vermont Piedmont, Northeastern Highlands and the Green Mountains. Watersheds or portions thereof involved in the Vermont Agricultural Runoff Study occur in all six physiographic regions.

The Champlain Lowlands contain the majority of watersheds studied including: Lower Otter Creek, Malletts Bay, Rock River and Pike Creek. In addition, portions of the Tyler Branch, Black Creek, Browns River, and mid-Otter Creeks Watersheds fall within the Champlain Lowlands. The Lowlands encompass Franklin, Chittenden, Addison, and portions of Rutland Counties and are comprised of gently rolling and broad low hills, lakeshore terraces, and fossil delta plains. They are bordered by the Green Mountains in the east and Adirondacks to the west and vary in width from twenty miles in the north to five miles in the south. The Lowlands extend south to the "hook" in the Poultney River in West Haven and north to the St. Lawrence Valley in Canada. Soils in the Lowlands are formed from lacustrine sands, silts, and clays with glacial drift occuring at slightly higher elevations. Fossil deltas and bench terraces are commonly found throughout the basin at relatively low elevations. Glacial gravels and alluvial deposits are found on the eastern base of the mountains. The occurrence of highly erodible clay soils varies throughout the Lowlands.

Data indicate that 63 percent of the erosion occurring in the nineteen watersheds sampled is found in the Champlain Lowlands. This erosion is associated with the fine-textured Vergennes and Covington soil series which are found predominantly in Addison County. Addison County contains 24 percent clay-textured soils compared to 8 and 6 percent in Franklin and Chittenden Counties, respectively. Soil erosion potential, based on the K value of the Universal Soil Loss Equation (USLE), indicates distinct differences between the major lake drainages (SCS, 1982). In the Champlain Basin, 73 percent of the cropland has high erosion potential. In the Memphremagog Basin, however, 82 percent of the cropland has low erosion potential and only 4 percent has high potential for erosion. Steepness of slope also varies, with Chittenden County exceeding 15 percent slope on almost two-thirds of the acreage. Slopes in Addison and Franklin Counties exceed 15 percent slope on about a third of the acreage.

The climate of the Lowlands is moderated due to proximity of Lake Champlain and adjacent mountain barriers. A growing season as long as 150 days and average annual precipitation of 33 inches, coupled with fertile soils, make the Champlain Lowlands one of Vermont's richest



Map 2.1 Physiographic Regions of Vermont

PHYSIOGRAPHIC REGIONS

From STEWART, DAVID P., THE GLACIAL GEOLOGY OF VERMONT. [illegible]

State Planning Office

agricultural assets. Consequently, much of the land is cleared and currently in agricultural use.

The Taconic Mountains contain only one major watershed which drains to Lake Champlain, namely the Mettawee River. The region lies to the south of the Champlain Lowland and the "hook" in the Poultney River, and to the west of Vermont Valley. The Taconics extend through southwestern Vermont approximately 80 miles and continue on into New York and Massachusetts. Soils in this physiographic region are mainly glacial tills with lake bottom sediments and gravels in valley bottoms. The region contains extensive forest and limited agricultural operations.

The Green Mountains are a prominent physical feature on the Vermont landscape extending 160 miles south from Canada to Massachusetts. They range in width from 20 to 36 miles. The average elevation is about 2,000 feet with Mount Mansfield, at 4,353 feet, the most prominent peak.

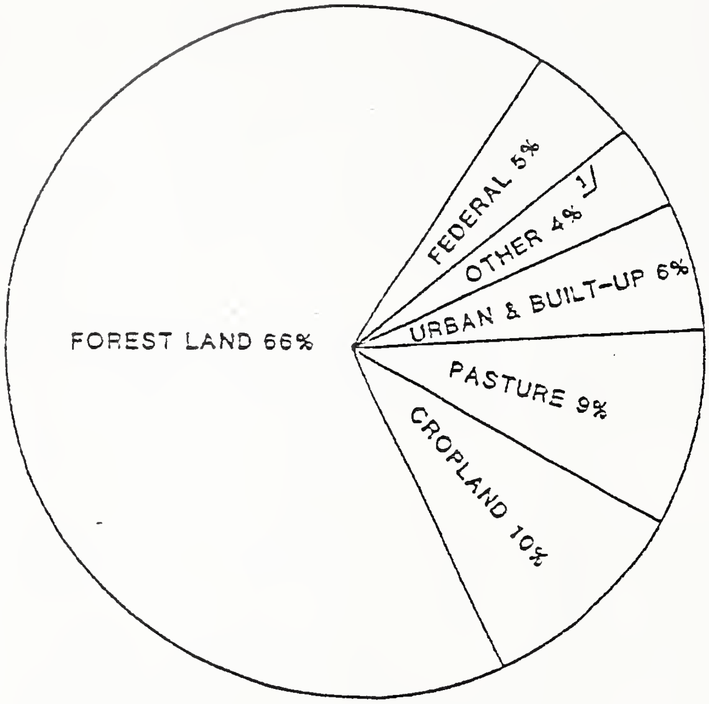
The entire Trout River Watershed and portions of the following watersheds are located within the Green Mountains physiographic region: Tyler Branch, Black Creek, Browns River, Lower Winooski, Lewis Creek, New Haven River, and mid-Otter Creek. Soils generally are of glacial till origin with lake sediment and gravels found on slopes below 2,000 feet. Climatic variability characterizes this physiographic region. Increases in rainfall occur with elevation.

The Vermont Piedmont is located between the Green Mountains and the Connecticut River and south of the northeastern Highlands. It extends nearly the full length of the State. Topography is typically low, rolling hills. Within the Piedmont two watersheds, the Clyde and Barton Rivers, drain northward to Lake Memphremagog. The soils are often stony, formed from glacial till with lake bottom sediments, sands, silts, and clays found along many river banks, particularly the fertile terraces of the Connecticut River. Climatic conditions vary considerably within this region. Typically, rainfall is from 34 to 50 inches, and the growing season ranges from 140 days near the Connecticut River to less than 110 days in upland areas.

The use of Vermont's land is determined in part by its soil, topography and climate. According to the 1977 National Resources Inventory, prepared by the Soil Conservation Service, just 10 percent of Vermont's 6,150,000 acres is in active crop production. Forest covers over two-thirds of the State.

In the decade from 1967 to 1977, the pattern of land use in Vermont changed substantially. Cropland and pasture land declined and forestland increased. Urban and built-up land increased by 100,000 acres, or 53 percent, over the decade.

Figure 2.1 Vermont Land Use in 1977 by Percent of Total Land Base



1/ "Other" includes noncensus water, small builtup areas (0.25 to 10 acres in size), farmsteads, and other land inside and outside of farms.

Table 2.1 shows how Vermont's cropland was used in 1977.

Table 2.1. Vermont Cropland Uses, 1977

Uses	Thousand Acres
Row crops	85
Close-grown crops	4
Rotation hay and pasture	182
Occasionally improved hayland	274
Native hay	25
Orchards and bush fruit	12
Other cropland	15
Total	597

The 19 watersheds under study lie mainly in Addison, Chittenden, Franklin, Orleans, and Rutland counties and drain Vermont's major dairy farming areas. Except for the intensively farmed watersheds in Addison County, the majority of the watersheds are heavily forested, with cropland and pasture covering less than 20 percent of the land area. Table 2.2 summarizes differences in land use by watershed.

Table 2.2 Existing Land Use in Selected Vermont Watersheds 1/ (% of Total Watershed Area)

Land Use	Watershed Number																		
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Continuous Rowcrop	1	<1	1	1	2	<1	<1	<1	1	1	1	<1	1	1	2	2	2	1	<1
Continuous Hay	8	13	5	21	7	14	6	5	4	11	5	3	2	5	6	6	4	14	6
Forest Land	80	74	91	53	50	71	54	78	67	36	68	42	82	24	34	74	79	27	76
Pasture	4	7	2	20	15	8	4	4	3	19	11	24	3	24	29	7	9	11	6
Tillage in Rotation	<1	1	0	3	15	3	<1	2	1	18	13	28	3	31	19	3	5	5	3
Urban	1	<1	<1	<1	<1	<1	5	<1	4	<1	<1	<1	<1	2	<1	1	<1	<1	<1
Water	6	4	<1	<1	4	1	2	<1	1	<1	1	1	<1	1	1	4	1	10	4
Wetlands	<1	1	1	2	4	3	3	3	4	2	1	2	<1	5	2	3	<1	6	2
Other	<1	<1	<1	<1	3	<1	26	8	15	13	<1	<1	9	7	7	1	<1	26	3

1/ Derived from Watershed Sampling and LANDSAT imagery interpretation.

No land use changes are projected here. Across Vermont there has been a gradual decline in cropland and pasture acreage with corresponding gains in urban and built-up land and forest land. This study assumes that agricultural land uses will remain constant through 1995.

Vermont classifies its agricultural soils into four categories with respect to agricultural use: highest, good, low and limited (Godfrey, 1982). The classification depends on the limitations and potentials of the soil, risks and damage associated with use and response to management. Highest and good categories meet the Vermont Act 250 criteria for Primary Agricultural Soils.

Using soil and field slope data on lands now producing row crops, estimates were made of the amount of prime farmland and primary agricultural land in each watershed, shown in Table 2.3.

Table 2.3. Estimates of Prime Farmland and Primary Agricultural Land in Row Crop Production, Agricultural Runoff Study Basins

	Prime Farmland (Highest Potential)	Primary Agricultural Land (Highest and Good Potential)
	Acres	
Champlain Basin	14,800	68,300
Memphremagog	160	1,300
Harvey's Lake	70	110
Shelburne Pond	0	170

Water Resources

Vermont abounds with inland lakes and ponds, streams and border waters. There are 280 lakes or ponds 20 acres or larger in the state. Twenty-one rivers have drainage areas over 100 square miles. Groundwater is plentiful in most areas of the state.

There are three principal drainage systems in the state -- the St. Lawrence River, the Connecticut River and the Hudson River. Watersheds in this study all drain to the St. Lawrence River via Lake Champlain and Lake Memphremagog except for Harvey's Lake which empties into the Connecticut River. Largest of the tributaries are the Barton, Black and Clyde Rivers, all emptying to Lake Memphremagog, and the Missisquoi, Lamoille, Winooski, Otter Creek and Mettawee Rivers, all discharging into Lake Champlain.

The State of Vermont has classified the streams of these tributaries for water quality management purposes. With the exception of short reaches below waste water treatment plant outfalls, most of the stream systems are classified as at least B, suitable for bathing, recreation, irrigation, agriculture, fish habitat, esthetic value and public water supply with filtration and disinfection.

Lake Champlain, the sixth largest freshwater lake in the United States at 435 square miles, acts as a boundary on Vermont's west side. A small portion of the lake also lies within Quebec Province on the north. This large lake is a haven for fishermen, year-round sports and tourism. Nearly every species of fish found in Vermont resides at one time or another in the lake. Lake Champlain lies close to 25 percent of the nation's population (as well as Canada's largest city) and has a recreation-tourism economy of over $100 million annually in the region. Sixteen of the study watersheds drain into Lake Champlain.

Forty miles to the east of Lake Champlain is Lake Memphremagog, the second largest of Vermont's shared lakes. This 32 square mile lake has about 9.9 square miles in Vermont. It is also important to

the local recreation-tourism economy and serves as a source of water supply for the cities of Magog and Sherbrooke, Quebec. Lake Memphremagog is an excellent warm and cold water fishery and is well known for its rainbow trout and bass. Two of the study watersheds empty to Lake Memphremagog.

Shelburne Pond and Harvey's Lake are inland waters which are also included in this study. Shelburne Pond, situated south of Burlington in Chittenden County, is 450 acres in size, shallow, and supports a good warm water fishery. Fishing is its primary recreational use. Harvey's Lake, south of St. Johnsbury in Caledonia County, is 409 acres in size, moderately deep, and supports both a warm and cold water fishery. It is heavily used for recreation and tourism.

All of these lakes and ponds are suffering from accelerated eutrophication influenced by cultural changes. Adverse effects on water use are accompanying this water quality deterioration.

SOCIAL AND ECONOMIC SETTING

Population

The natural resources described above acted as a magnet for people during the post-war era. Freed from traditional urban concentrations by improvements in communication and transportation, people flocked to Vermont's mountains and lakes. The first wave of new residents sought summer and winter recreational homes in the 1950s and 1960s, either in retirement or as second homes. More recently, however, full-time, permanent residents severed household and occupational ties in older developed areas of New England and the Mid-Atlantic to come to Vermont.

Population change in Vermont and the study counties is summarized in Table 2.4. Population grew only 3 percent in the decade of the 1950s. Between 1960 and 1980, however, population grew five times as fast, rising 15 percent each decade. Population growth in the counties containing the watersheds under study here was faster than for the State between 1950 and 1960 but grew at the same rate as the State in the 1970s. Population in the study watersheds was about a third of that in the counties in 1970. During the '70s watershed population increased faster than the counties or the State, growing 23 percent in the decade.

Within the study counties, Chittenden County has the largest population and has consistently grown at higher rates. Addison County had the lowest population in 1950 but has grown rapidly since 1960. Orleans and Franklin Counties reversed declines in population in the 1950s and showed population growth in the 1970s.

Table 2.4. Trends in Urban and Farm Population, 1950-1980.

Area	1950	1960	1970	1980	Percent Change 1950-60	1960-70	1970-80
Vermont	377,747	389,881	444,330	511,546	3.2	14.0	15.1
Study counties[1]	179,001	190,837	227,469	261,515	6.6	19.2	15.0
Urban population	77,672	87,388	95,069	115,139	12.5	8.8	21.1
Percent of total population	43.4	45.8	41.8	44.0	--	--	--
Farm operators and laborers[2]	10,555	7,254	4,385	5,143	-31.3	-39.6	17.3
Percent of total population	5.9	3.8	1.9	2.0	--	--	--

[1]Addison, Chittenden, Franklin, Orleans, and Rutland.
[2]Commercial (class 1-5) farm operators plus hired workers who worked more than 150 days per year. Data is for 1950, 1959, 1969 and 1978.

Over the post-war period, a fundamental change in patterns of living occurred which affects Vermont profoundly. Up until the mid-1960s, demographic movement was simultaneously out of central cities into suburban areas and from rural areas to metropolitan areas. During this period in Vermont, suburbs developed around established centers like Burlington, Rutland and St. Albans, while population in counties like Orleans and Franklin declined or grew only slightly. In the late 1960s and 1970s, population and employment moved away from metropolitan areas into previously rural areas. At the same time, the decline in farm population that has gone on since the turn of the century has stabilized and may have reversed in some areas. These movements blur the traditional distinction between urban and rural residents. Clearly, however, more nonfarm population is residing in previously rural areas of the State, and the distinction between farmers and other rural residents has become less meaningful.

Economy

Along with the influx of new residents, jobs increased in Vermont over the post-war period. Table 2.5 shows changes in employment in the study counties by major industry. As in the rest of the nation, jobs in Services and Government gained relative to other sectors during the 1960s; but growth in these sectors leveled out in the 1970s. Manufacturing remains the largest employer in the study counties but with a reduced dominance over earlier years. Agricultural employment (excluding farm operators) declined in importance until the mid-1970s but appears to have become more important in the late 1970s.

Within the agriculture sector in the study counties, the dominant trend is toward farms that are more commercial, more consolidated and more intensive, as shown in Table 2.6. The number of farms has been decreasing, and the remaining farms are larger. The average dairy herd in the study counties has increased 45 percent since 1964, while harvested cropland increased from 30 percent to 40 percent of all land in farms. Each cow is supported on less farmland than in 1964; and this trend is even more important than the numbers show since only about three-fourths of farms are dairy farms, compared to nine-tenths in 1964.

Within the watersheds, there were approximately 1,340 farms with 77,892 cows in 1977. This estimate was based on tax listers' reports for livestock and is not strictly comparable to Census data. However, this represents 64 percent of the herds recorded by tax listers in the study counties and 59 percent of the cows.

Vermont Dairy Farming

In the context of all agricultural activity in Vermont and the study area, dairy farming is the predominant agricultural enterprise. As shown above, 78 percent of farms in the study counties derived some

Table 2.5. Trends in Employment, Study Counties, 1963-1978[1]

Industry	1963-64	1967-69	1972-74	1977-78
		Paid employees (thousands)		
Agriculture[2]	2.4	1.6	1.8	2.5
Manufacturing	13.7	19.9	18.0	20.6
Retail trade	8.3	9.8	12.5	14.9
Wholesale trade	2.0	2.5	3.4	3.8
Services	2.2	3.3	5.4	6.0
Government[3]	3.3	4.1	6.2	6.5
Total	31.9	41.2	47.3	54.3
		Percent of total		
Agriculture	7.5	3.9	3.8	4.6
Manufacturing	42.9	48.3	38.0	37.9
Retail trade	26.0	23.7	26.4	27.4
Wholesale trade	6.3	6.1	7.2	7.0
Services	6.9	8.0	11.4	11.0
Government	10.3	10.0	13.2	12.0

[1]Addison, Chittenden, Franklin, Orleans, and Rutland.
[2]Hired farm labor working 150 days or more. Value for 1964 is for all farms, 1969-1978 is for Class I-V farms only.
[3]State and local government workers working within the county area.
Source: Census of Agriculture

Table 2.6. Trends in Commercial Agriculture, Study Counties, 1964-1978[1]

Item	1964	1969	1974	1978
Farms, number	3,864	2,799	2,633	2,588
Dairy farms, percent	88.6	87.0	81.9	78.9
Land in farms, acres	1,256,626	974,598	909,872	893,490
Harvested cropland, percent	31.3	32.9	35.6	39.2
Milk cows, number	144,281	121,371	126,354	124,720
Average dairy herd, number	42	50	58	61
Farmland acres per cow	8.7	8.0	7.2	7.2

[1]Addison, Chittenden, Franklin, Orleans, and Rutland.
Source: Census of Agriculture

income from the sale of dairy products in 1978. Tradition, short growing season, thin soils, proximity to the Boston market and relatively favorable and stable prices for dairy products help account for the dominance of dairy farming in Vermont agriculture. Nevertheless, dairy dominance has slipped somewhat in the post-war period.

Detailed information on dairy farms (SIC 024) is tabulated in the 1978 Census of Agriculture for Vermont. The average dairy farm has 362 acres, of which 144 are harvested as cropland and another 124 acres are pastured. Three-fourths of the land is owned by dairy farmers while one-fourth is rented from others. The average dairy farm has an investment of $225,287 in land and buildings and an additional $53,916 invested in machinery. Dairy farming is far more capital intensive than other types of farm operations in Vermont.

Almost 87 percent of dairy farms are family farms, while another 10 percent are partnerships. Only 3 percent are corporations, but three-fourths of these are family-held corporations. Ninety percent of farm operators live on their farms, and 94 percent list their occupation as "farming", with 73 percent reporting no work off the farm. Ninety-six percent of the operators are male, and their average age is 47.4 years.

Only 60 percent of Vermont dairy farmers grew corn in 1978. Ninety-six percent grew some hay crop and 43 percent grew alfalfa hay. Of the acres harvested as cropland on dairy farms, 20 percent was in corn and 79 percent in hay, with 1 percent in other crops. The average dairy farm had 58 milk cows and 32 heifers or heifer calves, in addition to various other livestock such as beef cattle, pigs, sheep and horses. Based on data from the New England Crop Reporting Service, Vermont farmers averaged 15 tons per acre of corn silage, 1.9 tons per acre of hay and 11,484 pounds of milk per cow in 1978.

The average Vermont dairy farm earned $74,553 from sales of agricultural products in 1978, 91 percent from dairy products, 8 percent from sales of cattle and calves, and the remainder from crop sales. To supplement crops fed to dairy cattle, an average of $24,019 was spent on purchased feeds, including 129.5 tons of commercial mixed feeds. An average of $4,591 was spent on seed and chemicals for crop production, but only 75-88 percent of dairy farms reported expenditures for these items. This includes an average of $2,848 for commercial fertilizer. Only 70 percent of cropland acres on dairy farms were treated with commercial fertilizer.

Water Resource Values

Efforts to maintain clean water should be viewed within the context of human use of those resources. Although the benefits of clean water accrue to a whole range of uses, the principal ones are recreational and water supply uses. The economic value of clean water in Vermont can be estimated by measurement of the scope and magnitude of these uses.

About a third of outdoor recreationists in the northeastern United States participate in activities that make direct use of water resources, such as swimming, fishing and boating (Bevins, et. al., 1979). Participation in these activities has been increasing, and

participants have traveled more frequently and further afield to participate in water-based recreation. Additional recreation participants, such as campers, picnickers and hikers, are influenced by the cleanliness of water resources near their recreation sites.

Information on water-based recreation in Vermont is confused since data have been collected for a variety of purposes and areas. Estimates in Table 2.7 were constructed from available data and provide only a rough guide. Residents are involved in 80 percent of the water-based recreation-day use in Vermont, but nonresidents account for more than half of total expenditures.

Table 2.7. User Days and Expenditures for Water-Based Recreation, Vermont, 1975

Activity	Annual User Days		Annual Expenditures[1]	
	Resident	Nonresident	Resident	Nonresident
	Thousands of user days		Thousands of dollars	
Swimming[2]	4,754.9	360.9	$ 1,325.2	$ 3,329.5
Boating[3]	651.5	116.3	2,962.7	3,517.8
Stream fishing[4]	1,332.3	268.8	4,423.3	6,005.4
Lake fishing[4]	847.6	324.0	8,831.4	11,393.6
Ice fishing[4]	327.4	34.8	2,199.2	879.2
Waterfowl hunting[4]	152.6	7.8	1,795.8	211.1
Total	4,754.9	1,112.7	$21,537.6	$25,336.5

[1]Adjusted to 1980 dollars by the Consumer Price Index. Does not include fixed expenditures for buildings or facilities.

[2]Based on Gilbert and Winant (1977) for Lake Champlain and assuming 20 percent are nonresidents. Expenditures assume $.60/day for residents. Nonresident expenditures are estimated at $20.50/day (SCORP, 1978) and 45 percent is attributed to swimming.

[3]Based on Gilbert and Winant (1977) for Lake Champlain and assuming three users per boat. Expenditures are per boat, except that nonresident expenditures include $20.50/day as tourists.

[4]Based on Gilbert (1981) for Vermont.

Total direct water-based recreation expenditures are estimated as 46.8 million dollars annually. A little less than one-third of these expenditures are for transportation, 15 percent for retail goods, and the remainder for services including lodgings, restaurants, and recreational facilities. Indirect economic impacts of these expenditures in the Burlington Economic Area, shown in Table 2.8, account for an additional 54.3 million dollars, for a total estimated economic impact of 101.1 million dollars annually.

Table 2.8. Secondary Impact of Recreational Expenditures, Burlington Economic Area, 1975

Activity	Transportation Communication and Utilities	Wholesale and Retail Trade	Services
	Thousands of dollars[1]		
Swimming	$ 1,325.4	$ 0.0	$ 3,329.3
Boating	1,054.3	0.0	5,426.2
Fishing			
Stream	3,466.4	2,350.5	4,611.8
Lake	5,925.1	3,024.2	11,275.7
Ice	1,364.3	582.5	1,131.6
Waterfowl hunting	602.7	944.8	459.4
Total	$13,738.2	$ 6,902.0	$26,234.0
Multiplier[2]	2.111	.602	2.592
Final demand	$29,001.3	$4,156.4	$67,998.5
Total final demand		$101,156.2	

[1]Adjusted to 1980 dollars by the Consumer Price Index.
[2]Based on Bureau of Economic Analysis Regional Impact Multiplier System (RIMS). Multiplier for Trade sector assumes a 24 percent gross trade margin.

Comparable estimates from some other sources support these figures. The Vermont State Comprehensive Outdoor Recreation Plan (SCORP, 1978) estimates that "vacation travel" contributed 405 million dollars (14 percent) of the State's gross product in 1976. Summer visitor expenditures were estimated at 145 million dollars for 1975, or about 222 million dollars when adjusted to 1980 dollars. Water-based recreation would thus account for about one-fifth of all summer recreation expenditures. Sales of selected retail and service sectors also support recreation expenditures in the 200- to 300-million-dollar range. Gilbert and Winant (1977), from which some of the data used above were drawn, estimated water-oriented recreational expenditures on the Vermont shore of Lake Champlain to be 34.1 million dollars annually (adjusted to 1980 dollars). Gilbert also estimated expenditures by fishermen in Orleans County to be 4.0 million dollars annually.

Another aspect of recreational water use is vacation homes located along the lake shore. Decreased water quality could lower property values for such property. A statistical analysis of fifty sales of residential property on or near St. Albans Bay attempted to estimate the effect of water quality, controlling for other property characteristics which would affect property value. The entire Bay was

considered to be eutrophic, so that residences located on the Bay should be worth less than similar properties located on unpolluted parts of Lake Champlain. Results showed an increase in value of about $3,500 for location on the Lake, but a decrease in value of about $4,600 for location on St. Albans Bay. However, these coefficients were only statistically significant at the 84 and 88 percent confidence levels, respectively. Nevertheless, it seems clear that some diminution in property values due to water pollution is occurring.

Water supply usage of the two major lakes is shown in Table 2.9. The Vermont Department of Health requires all municipal water systems using surface waters to filter and disinfect supplies. This level of treatment would be sufficient for all foreseeable pollutant levels, even in the absence of control programs. Therefore, no benefits are likely to accrue from forestalling increased water supply treatment costs.

Table 2.9. Water Supply Use, Lake Champlain and Lake Memphremagog

Area	Plants	Population Served	Average Daily Demand
	Number	Thousands	Million gallons/day
Lake Champlain Vermont[1]	16	107.9	13.8
Lake Memphremagog Canada[2]	2	89.0	17.5

[1]State of Vermont, Department of Health.
[2]New England River Basin Commission, "Lake Memphremagog/St. Francis River Basin Overview", 1981.

Any discussion of potential benefits from water quality protection or improvement must deal with the fact that the link between water use and water pollution is not well understood. We can describe how changes in pollutant loadings are likely to affect ecosystems and how water users will react to these changes. However, the ability to quantify all of these steps in the process is still spotty, so accurate benefit estimates cannot be made.

Concerning the effect of algae blooms on water users, the critical element for benefit estimation, almost nothing is known. In extreme situations the response is dramatic. For example, algae blooms and nuisance aquatic plants forced the closing of St. Albans Bay State Park and attendance dropped from 3,261 day users to zero. However, we do not know how water users will react to smaller increases in eutrophication. For example, how many swimmers, boaters, and fishermen will stop coming to Lake Champlain for each 1 percent

increase in chlorophyll-a measured in the Lake? More difficult still, what will a small change in phosphorus runoff from agriculture do to the amount of water-based recreation in the lakes? Until these questions can be answered quantitatively, no meaningful estimate of benefits can be made.

CHAPTER 3

THE AGING OF VERMONT LAKES

THE AGING PROCESS

The major water quality problem facing lakes in the study area is their trophic state. Eutrophication is the process of enriching a lake's waters with dissolved nutrients producing seasonal explosions in algal and rooted plant populations. While all lakes eutrophy over time, man's activities dramatically accelerate this process. In this context, sediment and nutrients which run off the land are pollutants.

Vermont lakes vary considerably in their stage of biological and nutrient enrichment. Those which are deep, cold, and biologically unproductive are considered young or in an oligotrophic stage. Others, due to their formation or through years of sediment influx, are shallow, warm, and support substantial growths of algae and rooted aquatic plants. These are considered old or in a eutrophic stage. Some lakes, such as Lake Champlain, have both oligotrophic and eutrophic segments along with other segments in a medium range called mesotrophic. The rate at which each lake eutrophys depends on its shape and the characteristics of its drainage basin.

The critical limiting nutrient for eutrophication in most Vermont lakes is phosphorus. Phosphorus enters the lakes in both adsorbed and dissolved forms. Adsorbed phosphorus is attached to soil particles and other mineral or organic matter and is largely unavailable for plant growth. It is estimated that about 20 percent of this fraction can become available to plants (Lee, et. al., 1980; Lake, 1977). More phosphorus desorbs from the soil particles as chemical, biological and thermal cycling occurs in the lake. Dissolved phosphorus enters the lakes primarily from plant and animal wastes and urban effluent. Dissolved phosphorus is readily available for plant growth.

Once phosphorus enters streams and lakes, its availability for plant uptake is difficult to predict. Phosphorus readily becomes associated with minerals and organisms and cycles from dissolved to adsorbed state. Recognition of this cycling is comparatively recent and many specialists do not make the distinction, identifying concentrations and loads in terms of total phosphorus. Existing trophic state models almost all use total phosphorus as an input.

There are a number of indicators used to identify the trophic condition of lakes. Three of the most common indicators are chlorophyll-a content, Secchi disk measurement, and spring or summer phosphorus concentration. Chlorophyll-a is a green photosynthetic pigment commonly found in planktonic algae. It is measured by spectrophotometric or other methods and is expressed in mass per unit volume of water. The Secchi disk measures lake water transparency based on the depth of which a standard disc disappears as viewed from the water surface. Spring and summer phosphorus concentrations indicate the general maximum concentration of phosphorus expected in the peak period of algae growth.

Eutrophication can be summed up in this way:

> "Eutrophication is unmistakable. Overstimulation of plant growth occurs with consequent deterioration in water quality and changes in fish species. Heavy growth of blue-green algae makes the lake green and murky, with seasonal algal blooms and scums and mats formed by deteriorating plants. Excessive growth of macrophytes -- rooted acquatic plants -- may clog the lake, making it unattractive for swimmers, boaters and fishermen. Unpleasant odors and tastes are noticed as decomposition of plants results in depleted oxygen supply ..."(Horwitz, 1980).

Conceptually, the process of eutrophication can be shown as in Figure 3.1. Point and nonpoint sources discharge phosphorus into receiving waters, often in "pulses" associated with runoff events. The phosphorus can be tied up in bottom sediments or stream bank vegetation, or can be released from these sinks when ambient concentrations become low enough. Higher phosphorus concentrations in lakes, along with favorable light, temperature and current conditions, allow the growth of abnormally high algae populations called "blooms". When the pulse of phosphorus recedes, or other factors change, the blooms die off. Decomposing algal masses are unsightly and the process ties up dissolved oxygen. Fish and other aquatic organisms literally suffocate. Decomposition releases unpleasant odors, tastes, and colors in the water and can yield toxic by-products. Decomposition products have impacts on wildlife which affect fishing and hunting uses of the water. The unpleasant smells, tastes and color, as well as the rotting algal masses, detract from swimming, boating and other water-based recreation. Property located on eutrophying water bodies loses value. The odors, tastes and color can reduce palatability of water supplies and increase treatment costs.

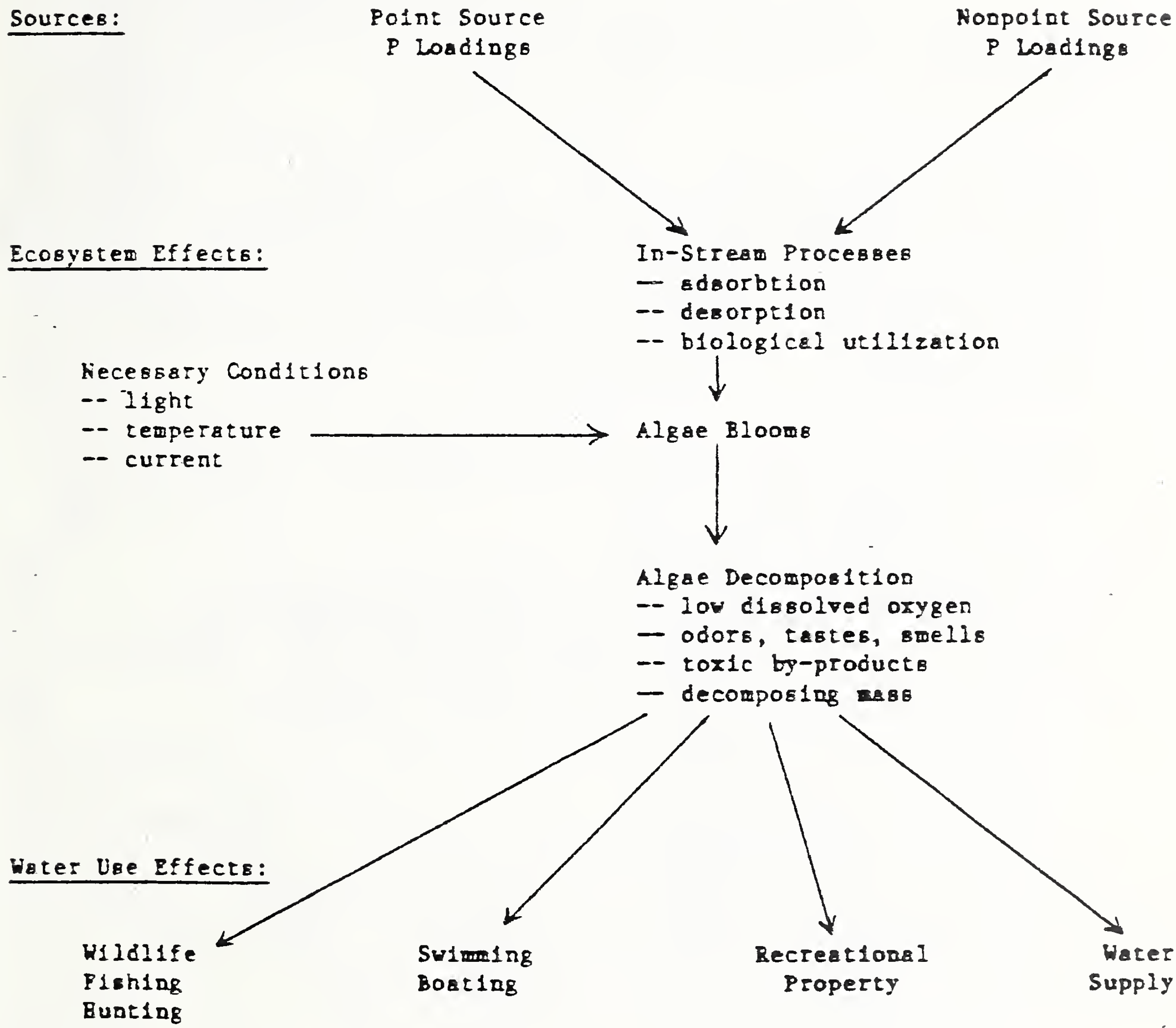
LAKE TROPHIC CONDITION

This study focuses on agricultural watersheds draining into Lake Champlain, Lake Memphremagog, Harvey's Lake, and Shelburne Pond. These waters are of primary concern to Vermonters for sediment and nutrient management to retard eutrophication. Each lake is discussed individually.

Lake Champlain

Lake Champlain is one of the Nation's largest lakes. It varies considerably from south to north in width, depth, shoreline configuration, biota, water quality and trophic state. The lake covers 435 square miles over a surface which extends 120 miles north-south, yet is only 12 miles broad at its maximum east-west width.

Figure 3.1. Processes of Eutrophication

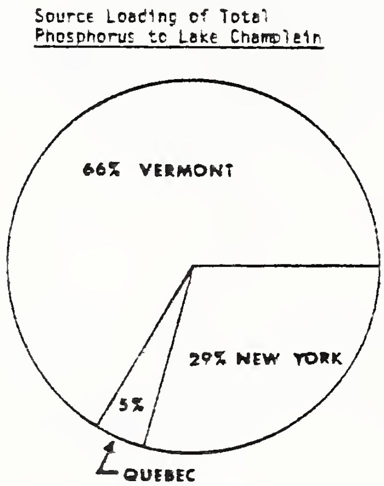


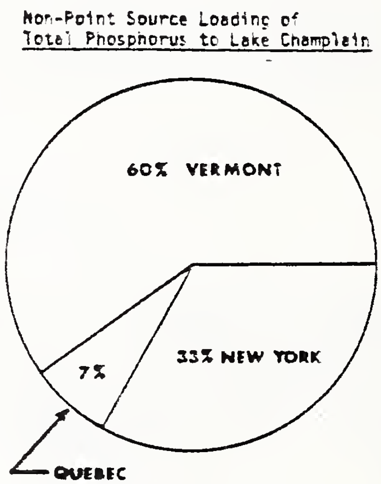
Parts of the lake are very deep — up to 400 feet. Its mean depth is 64 feet. About 20 percent of the lake is less than 13 feet in depth. This shallow zone borders all the shoreline areas.

Nuisance eutrophication is most noticeable in the shallow zone because: (1) most recreational and other uses of the lake are centered there, and (2) most of the lake's rooted aquatic plants grow in this zone. There are problems around the lake with excessive algae growth, increasing turbidity and prolific rooted plant growth. Missisquoi Bay, St. Albans Bay, Shelburne Bay and Red Rock Bay are well-known examples of areas experiencing these problems. There are many others.

Nutrient runoff to the lake varies throughout the year and from year to year depending upon rainfall, snowfall and snow melt conditions. The average annual phosphorus load to the lake from all sources totals 1,401,000 pounds (636,000 kilograms). Of this total about 66 percent is from Vermont sources, 29 percent from New York and 5 percent from Quebec. Nonpoint sources contribute 52 percent of the total phosphorus load. Vermont provides 60 percent of the nonpoint source phosphorus load, New York 33 percent and Quebec 7 percent. (See Figure 3.2.)

Figure 3.2. Origin of Total Phosphorus Loads to Lake Champlain





The lake can be divided into five water quality management areas (WQMA) according to physical, chemical and biological features: South Lake, Main Lake, Northeast Arm, Malletts Bay, and Missisquoi Bay (see Map 3.3). Table 3.1 shows estimated point and nonpoint total phosphorus loads to these WQMA's using commonly accepted values developed by Bogdan in 1978. Table 3.2 summarizes selected chemical and physical characteristics of the WQMA's.

Map 3.1 Principal Lake Champlain Subbasins and Water Quality Management Areas in Vermont

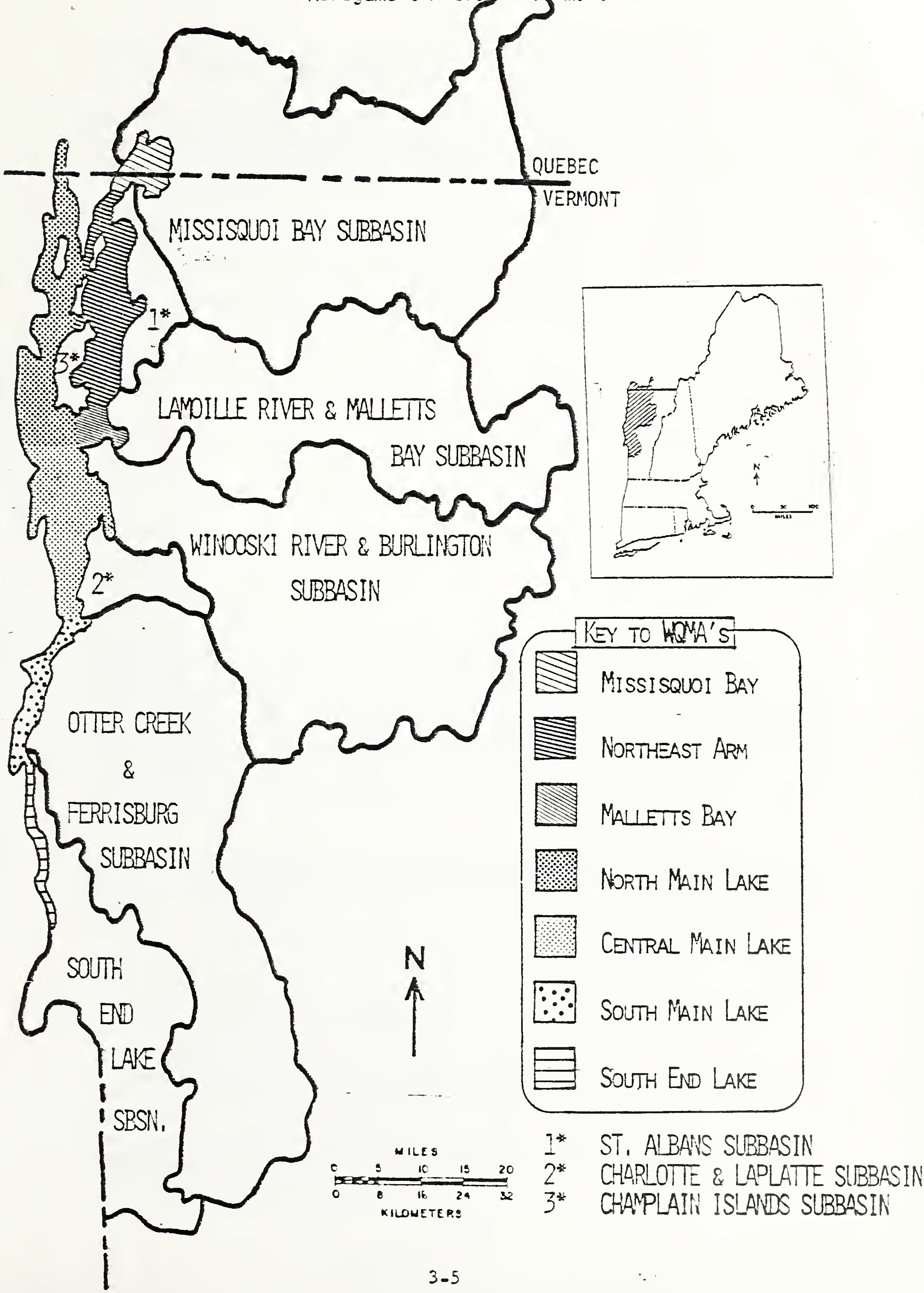


Table 3.1. Mean Total Phosphorus Load to Water Quality Management Areas (WQMA's)

	WQMA				
	Missisquoi Bay	Northeast Arm	Malletts Bay	South Lake[1]	Main Lake
Mean annual total phosphorus (pounds)	201,940	62,610	93,480	60,800	561,070
Nonpoint sources (pounds)	125,200	24,150	63,750	44,580	225,590
Nonpoint as percent of total	62	38	68	73	40
Agricultural as percent of nonpoint	78	66	55	71	60
Forest as percent of nonpoint	6	3	12	10	10

[1]Vermont portion only.
Source: Bogdan (1978).

Missisquoi Bay and the South Lake are most eutrophic when considering the values of Secchi disk and total phosphate-P. The Northeast Arm and the Main Lake appear to be mesotrophic by these indicators. An examination of an entire WQMA, however, ignores the fact that near shore portions can be very eutrophic. St. Albans Bay, within the Northeast Arm, is highly eutrophic; and Shelburne Bay, a part of the Main Lake WQMA, is more eutrophic than the Main Lake. Thus, each of the lake's water masses is experiencing eutrophication to some degree.

Chlorophyll-a values show Missisquoi Bay and the South Lake as most enriched. An examination of each of the lake's masses from north to south follows.

Missisquoi Bay

Missisquoi Bay is one of the most eutrophic sections of the lake. It generally has no thermal stratification and mixes well from top to bottom. It has the second highest phosphorus concentrations of the lake masses. It is very turbid with low Secchi disk readings attributable to both phytoplankton and suspended sediment.

Over the years diatoms have been the dominant phytoplankton group. Blue-green algae populations have been on the increase and are

Table 3.2. Summary of Physical and Chemical Characteristics of Water Quality Management Areas (WQMA's)

	WQMA				
	Missisquoi Bay	Northeast Arm	Malletts Bay	South Lake	Main Lake
Surface area Mi^2	29.9	103.7	20.9	22.0	263.5
Volume (thousand ac.-ft.)	173.7	2,796.9	566.9	126.0	17,024.9
Maximum depth (ft.)	13.0	161.0	105.0	46.0	400.0
Mean depth (ft.)	9.2	42.0	42.3	8.8	101.0
Retention time (yrs.)	0.3	1.0	0.6	0.1	2.8
Mean Secchi disk (M)	1.6	5.5	4.4	0.7	4.4
Mean total phosphate (mg/l)	.050	N/A	.012	.050	.018
Mean chlorophyll-a (mg/l)	10.0	3.5	6.2	10.1	3.8
Trophic classification	E	M	O-M	E	M

Source: Henson and Gruendling (1977).

extensive. A very offensive, blue-green bloom occurred in the summer of 1981. This bloom was unusually dense and long-lived. At its height the bloom halted the normally heavy recreational use of the bay. Rooted aquatic vegetation covers much of the Vermont portion of the bay. The progressive deterioration of the bay concerns Americans and Canadians alike. Both Environment Canada and the Vermont Agency of Environmental Conservation are increasing monitoring activities of the bay and its drainage basin. They are examining management alternatives and coordinating activities at the provincial-state level.

Runoff enters the bay from three principal tributaries -- Pike River, Rock River and the Missisquoi River (see Map 3.2 at the end of this chapter). The estimated annual total phosphorus yield to the bay from these tributaries is 201,940 pounds (Bogdan, 1978). Surrogate estimates developed during this study of the tributary and subtributary yields are provided in Table 3.3.

Table 3.3 Estimates of Annual Total Phosphorus Loads to the Missiquoi Bay WQMA of Lake Champlain

Sub-Basin	Watershed or Area	(1) Drainage Area-Acres	(2) All Total Phosphorus LBS	(3) All Total Phosphorus % of Sub-Basin	(4) Point Source (LBS)	(5) Non-Point Source LBS	(6) Non-Point Source % of (2)	(7) Non-Point Source Agric (LBS)	(8) Non-Point Source Agric-% of (5)	(9) Non-Point Source Forest (LBS)	(10) Non-Point Source Forest % of (5)
					Values Expressed in Terms of Estimated Annual Total Phosphorus						
1	All [2/]	732,150	277,650	100	80,190	197,460	71	177,460	90	13,910	7
	Missisquoi R.[1/]	547,200	137,380	49	57,700	79,680	58	63,670	80	11,120	14
	Trout R. (3)	50,340	5,010	2	0	5,010	100	3,320	66	1,560	31
	Tyler R. (4)	35,920	39,000	14	25,250	13,750	35	13,110	95	570	4
	Black C. (6)	75,790	8,620	3	0	8,620	100	6,570	76	1,830	21
	Rock River and Pike Creek (5)	47,900	45,850	17	14,890	30,960	68	29,880	97	730	2
	Canadian Portion	137,050	94,420	34	7,600	86,820	92	83,910	97	2,010	2
Bogdan 1978 Estimate	All		201,940	100		125,200	62		78		6
Adjustment Ratio (Bogdan÷ Surrogate)						0.60					

1/ All of Missisquoi River Basin including watersheds 3, 4 and 6.

2/ Includes the Missisquoi River, Watershed 5 and Canadian Portion Drainage.

Source: Agriculture and forest land - this study; other loads from unit values in (Loehr, 1974) and from Vermont Department of Water Resources and Environmental Engineering.

Malletts Bay

Malletts Bay is a heavily used recreational resource. The bay is in transition from oligotrophic to mesotrophic. The bay strongly stratifies and exhibits severe oxygen depletion in bottom water during summer and early fall. Large amounts of biological oxygen demand (BOD) discharged from the Lamoille River are probably aggravating this situation.

There is a noticeable absence of the blue-green algae in this part of the lake although other algal populations, dominated by diatoms, are normally high. Several species of nuisance macrophytes persist in Malletts Bay but have not been a major problem.

Tributaries of the sub-basin are the Lamoille River and Malletts Creek. The Browns River (8) and Malletts Bay (7) Watersheds have been evaluated as a part of this study. Map 3.3 shows a map of the sub-basin.

Total phosphorus yield estimates for various portions of the sub-basin are provided in Table 3.4.

Main Lake

The Main Lake is the largest of the water masses and is often regarded as having three distinct segments. The south segment extends from the Crown Point Bridge north to Thompson's Point. The central portion occupies the area from there north to Cumberland Head, New York. The north segment includes the balance of the lake north to its outlet at the Richelieu River. The north segment is remote from any drainage covered as part of this study.

All of the Main Lake strongly stratifies. The bottom water is generally at or near oxygen saturation. Water clarity is good and is exceeded only by that in the Northeast Arm. Clarity tends to increase from south to north. Shallow, near-shore areas are much more turbid. Total phosphorus concentrations are in the mesotrophic range. The shallower portions of the Main Lake, such as Burlington Bay and Shelburne Bay, have elevated total phosphorus concentrations. Algal populations and types found in the Main Lake are indicative of a mesotrophic condition, although some of the near-shore areas are in a eutrophic condition. There are isolated, serious infestations of rooted plants. These areas are near shore where depths are less than 13 feet. Shelburne Bay is a good example. At a Main Lake water quality monitoring station with long-term records, a ten-year trend in transparency (Secchi Disc 1965-1974) has been towards reduced clarity. Values in 1965 ranged from 4.5 to 6.0 meters and diminished to 1974 ranges of 2.5 to 4.5 meters.

The central portion of the Main Lake receives runoff on the Vermont side from the Winooski River-Burlington sub-basin and from the Charlotte area. There is a minor amount of runoff from the Champlain

Table 3.4 Estimates of Annual Total Phosphorus Loads to the Malletts Bay WQMA of Lake Champlain

Sub-Basin	Watershed or Area	(1) Drainage Area-Acres	(2) All Total Phosphorus LBS	(3) All Total Phosphorus % of Sub-Basin	(4) Point Source (LBS)	(5) Non-Point Source LBS	(6) Non-Point Source % of (2)	(7) Agric (LBS)	(8) Agric-% of (5)	(9) Forest (LBS)	(10) Forest % of (6)
3	All 2/	480,240	102,060	100	30,280	71,780	70	53,460	74	12,765	18
	Lamoille River 1/	451,840	98,230	96	30,280	67,950	69	52,180	77	12,310	18
	Browns River (8)	59,330	10,380	10	0	10,380	100	8,130	78	1,420	14
	Malletts Bay (7)	28,400	3,830	4	0	3,830	100	1,280	33	460	12
	Bogdan 1978 Estimate All		93,480			63,750	68		55		12
	Adjustment Ratio (Bogdan ÷ Surrogate)					0.90					

1/ All of Lamoille River Drainage including Watershed 8.

2/ Includes the Lamoille River and Malletts Bay Drainage.

Source: Agriculture and forest land - this study; other loads from unit values (Loehr, 1974) and from Vermont Department of Water Resources and Environmental Engineering.

Islands. The LaPlatte Watershed PL-566 project is addressing agricultural nonpoint runoff into Shelburne Bay, so that area is not covered in this study. Study watersheds in the central Main Lake subbasin are the Lower Winooski River (9) and the northern section of the Lake Champlain Direct (10). Map 3.4 shows the Vermont portion of drainage to central Main Lake Champlain. Table 3.5 provides annual estimates of total phosphorus yields from the Vermont sub-basins to the central Main Lake.

The south segment of Main Lake Champlain (Crown Point Bridge to Thompson's Point) receives runoff from the Otter Creek and Ferrisburg sub-basin. Study watersheds in this sub-basin are Lewis Creek (11), Little Otter Creek (12), New Haven River (13), Dead Creek-Otter Creek (14), Lemon-Fair River (15), Mid-Otter Creek (16) and a portion of the direct drainage to Lake Champlain (10). Map 3.5 shows the principal Vermont drainage to south Main Lake Champlain. Table 3.6 provides estimated annual total phosphorus loads from Vermont sub-basins into the South Main Lake Champlain segment.

South Lake

This long, narrow, shallow portion of the lake seldom stratifies. Bottom oxygen is generally at or near saturation. Water temperature is generally higher than other sections of the lake. Total phosphorus concentrations are as high as any in the lake. These high phosphorus concentrations flow into the main lake and cause algal blooms in the southern Main Lake segment just north of the Crown Point Bridge and surrounding the Port Henry, New York, area. Although the total phosphorus concentrations are high in the South Lake, massive algal blooms have not occurred there primarily because of the high turbidity. It is the most turbid section of the lake by far. The high turbidity has not been effective, however, in keeping out nuisance aquatic weeds. Five of the seven most troublesome weeds in the lake are found here. Water chestnut mixed with yellow floating-heart infestations have essentially closed in Herrick's Bay, Pickeral Bay, Peters Bay and Red Rock Bay. The Vermont Department of Water Resources has applied to the Corps of Engineers, New York District, for assistance in developing an aquatic plant management program under Section 302, Public Law 89-298. They expect to commence a ten-year harvesting program in summer 1982.

The two main Vermont tributaries of the South sub-basin are the Poultney River and the Mettawee River. The Mettawee Watershed (17) is included in this study. See Map 3.6 for general location. The total phosphorus yields for the sub-basin are provided in Table 3.7.

Table 3.5 Estimates of Annual Total Phosphorus Loads from Vermont Subbasins to the Central Main Lake Champlain Segment

		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Sub-Basin	Watershed	Acres	Values Expressed in Terms of Estimated Annual Total Phosphorus								
			All Total Phosphorus			Non-Point Source					
			LBS	% of Sub-basin	Point Source (LBS)	LBS	% of (2)	Agric (LBS)	Agric-% of (5)	Forest (LBS)	Forest % of (5)
5	All	748,420	353,420	100	243,850	109,570	31	54,690	50	15,010	12
	Winooski R.	691,200	337,710	96	243,850	93,860	28	41,060	44	14,785	16
	Lower Winooski R. (9)	144,590	104,525	30	84,935	19,590	19	8,160	42	2,965	15
	Direct Drainage (10) Portion	15,000	12,840	<4	0	12,840	100	12,450	97	170	<1
	Charlotte (from Bogdan, 1978)	4,660	2,870	<1		2,870	100	1,180	41	55	2
Bogdan 1978 Estimate All			265,200	100		66,300	25		45		12
Adjustment Ratio (Bogdan + Surrogate)						0.52					

Source: Agriculture and forest land - this study; other loads from unit values in (Loehr, 1974) and from Vermont Department of Water Resources and Environmental Engineering.

Table 3.6 Estimates of Annual Total Phosphorus Loads from Vermont Subbasins into the South Main Lake Champlain Segment

Sub-Basin	Watershed or Area	(1) Drainage Area-Acres	(2) All Total Phosphorus: LBS	(3) All Total Phosphorus: % of Sub-Basin	(4) Point Source (LBS)	(5) Non-Point Source: LBS	(6) Non-Point Source: % of (2)	(7) Non-Point Source: Agric (LBS)	(8) Non-Point Source: Agric-% of (5)	(9) Non-Point Source: Forest (LBS)	(10) Non-Point Source: Forest % of (5)
			Values Expressed in Terms of Estimated Annual Total Phosphorus								
6	All	703,330	399,630	100	90,860	308,770	77	277,490	90	16,050	5
	Lewis Creek (11)	51,290	17,710	4	C	17,710	100	16,510	93	1,080	<6
	Little Otter (12)	43,500	42,920	11	0	42,920	100	42,080	98	570	<1
	Otter Creek	599,040	330,900	83	90,860	240,040	73	211,040	88	14,290	6
	New Havem (13)	74,410	10,400	3	0	10,400	100	6,410	62	1,950	19
	LODC (14)	67,600	66,030	17	6,000	60,030	91	57,260	95	2,120	4
	Lemon Fair (15)	55,800	67,150	17	0	67,150	100	64,760	96	600	<1
	Mid Otter (16)	128,490	31,390	8	12,340	19,050	61	15,390	81	2,960	16
	Direct Drainage	9,500	8,100	2	0	8,100	100	7,860	97	110	1
Bogdan 1978 Estimate	All		231,000	100	0	149,910	65		70		9
Adjustment Ratio (Bogdan÷ Surrogate)						0.43					

Source: Agriculture and forests - this study; other loads from unit values in (Loehr, 1974) and from Vermont Department of Water Resources and Environmental Engineering.

Table 3.7 Estimates of Annual Total Phosphorus Loads from Vermont Subbasins into the South Lake Segment of Lake Champlain

		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Sub-Basin	Watershed or Area	Drainage Area-Acres	Values Expressed in Terms of Estimated Annual Total Phosphorus								
			All Total Phosphorus			Non-Point Source					
			LBS	% of Sub-Basin	Point Source (LBS)	LBS	% of (2)	Agric (LBS)	Agric-% of (5)	Forest (LBS)	Forest % of (5)
7	All	290,870	110,250	100	16,270	93,980	85	85,690	91	5,740	6
	Mettawee R. (17)	72,870	17,290	16	4,390	12,900	75	11,030	86	1,730	13
	Direct Drainage (10)	54,600	47,180	43	400	46,780	99	45,200	97	790	2
	Poultney R.	151,040	45,780	41	11,480	34,300	75	29,460	86	3,220	9
Bogdan 1978 Estimate			60,800	100		44,580	73		71		10
Adjustment Ratio (Bogdan ÷ Surrogate)						0.67					

Source: Agriculture and forests - this study; other loads from unit values in (Loehr, 1974) and from Vermont Department of Water Resources and Environmental Engineering.

Lake Memphremagog

Like Lake Champlain, Lake Memphremagog straddles the U.S.-Canadian border and has approximately one-third of its 36.5 square-mile surface lying in the United States. Average depth of the lake is 55 feet. It is 25 miles long and averages 1.5 miles wide. Nearly 70 percent of the basin's 652 square miles is drained by three Vermont rivers -- the Black, the Barton (2) and the Clyde (1).

Like other Vermont lakes, Memphremagog is phosphorus limited. Accelerated eutrophication is occurring in Newport Bay (mean depth is 30 feet) and South Basin (mean depth is 28 feet) where the lake is not only the shallowest, but at this point receives over half of the total phosphorus entering the lake from nonpoint sources (see Map 3.7). This area of the lake has had a history of algal blooms, low dissolved oxygen and excessive aquatic weed growth.

Lake Memphremagog can be divided into four major segments as shown in Map 3.7. Table 3.8 provides morphometry and trophic conditions of each of these segments.

Table 3.8. Morphometric Characteristics of Lake Memphremagog

Segment	Surface Area Mi^2	Water Volume Ac. Ft.	Mean Depth Ft.	Trophic Condition
Newport Bay	0.74	12,128	25.6	Eutrophic
South Basin	15.45	232,941	23.6	Eutrophic
Central Basin	8.46	875,646	161.7	Oligotrophic
North Basin	7.37	208,109	44.1	Mesotrophic
Total lake	32.02	1,328,824	64.8	--

A tertiary level waste water treatment facility is being constructed at Newport. When this facility goes into operation in 1984, the Newport point source load will be reduced in concentration to 1.0 mg/l of phosphorus. The predicted phosphorus concentrations in Newport Bay and South Basin are provided in Figure 3.3. This shows that Newport Bay will continue to be eutrophic and South Basin mesotrophic. Nonpoint source phosphorus management is needed to bring these concentrations down to an acceptable trophic state (see Chapter 7).

The average annual estimate of total phosphorus load to the lake from all sources is 63,970 pounds. Of this total about 84 percent is from Vermont sources. This will change when Newport's tertiary level wastewater treatment plant comes on line in 1984. At that time about 79 percent of the lake's phosphorus load will be provided by the three Vermont rivers. Loading from Newport and direct drainage accounts for the balance of Vermont's phosphorus load. Figure 3.4 illustrates these relationships.

Map 3.7 Lake Memphremagog Water Quality Management Areas and Major Vermont Subbasins

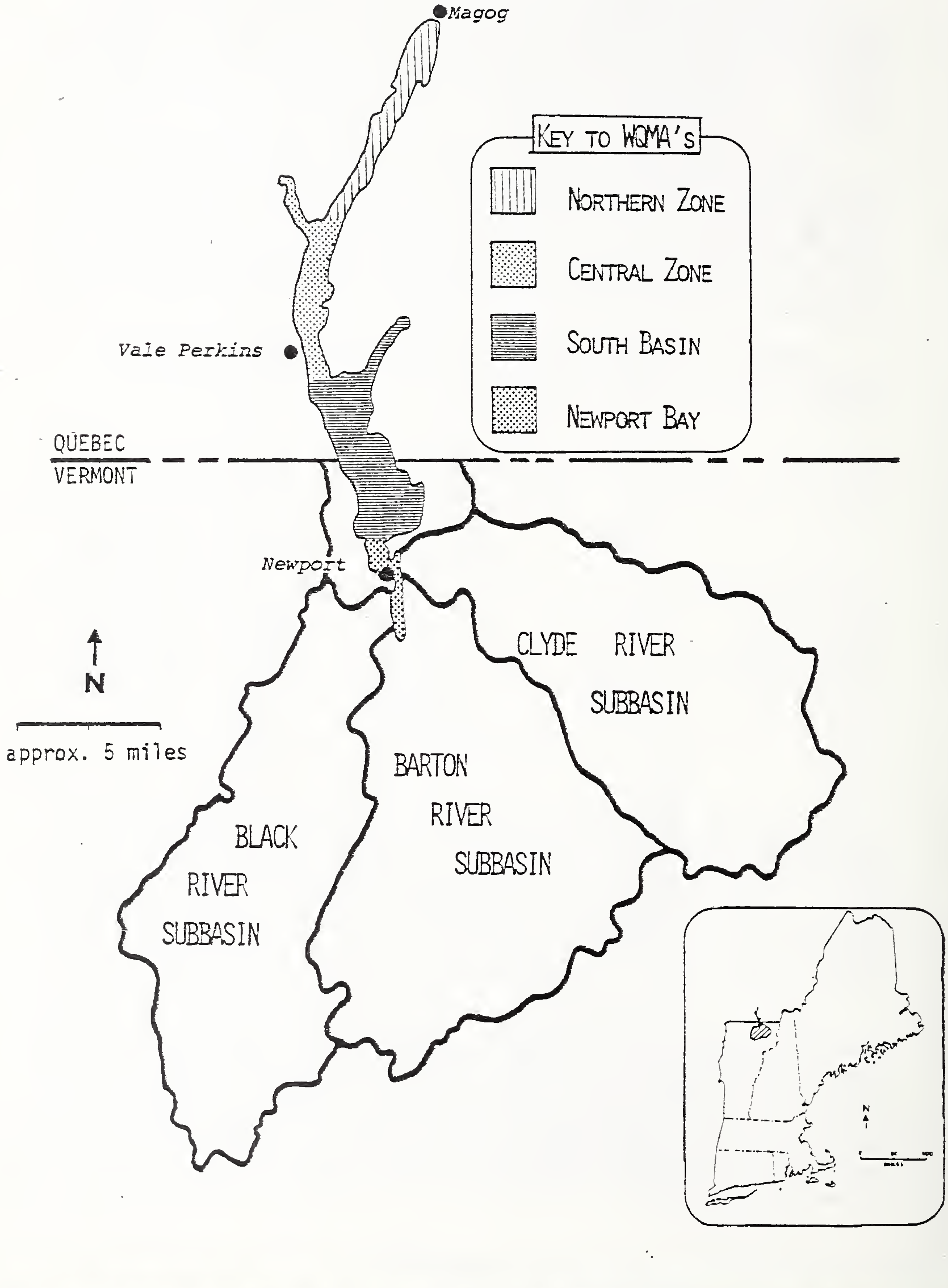


FIG. 3.3 PREDICTED TROPHIC STATE OF NEWPORT BAY AND SOUTH BASIN (LAKE MEMPHREMAGOG)

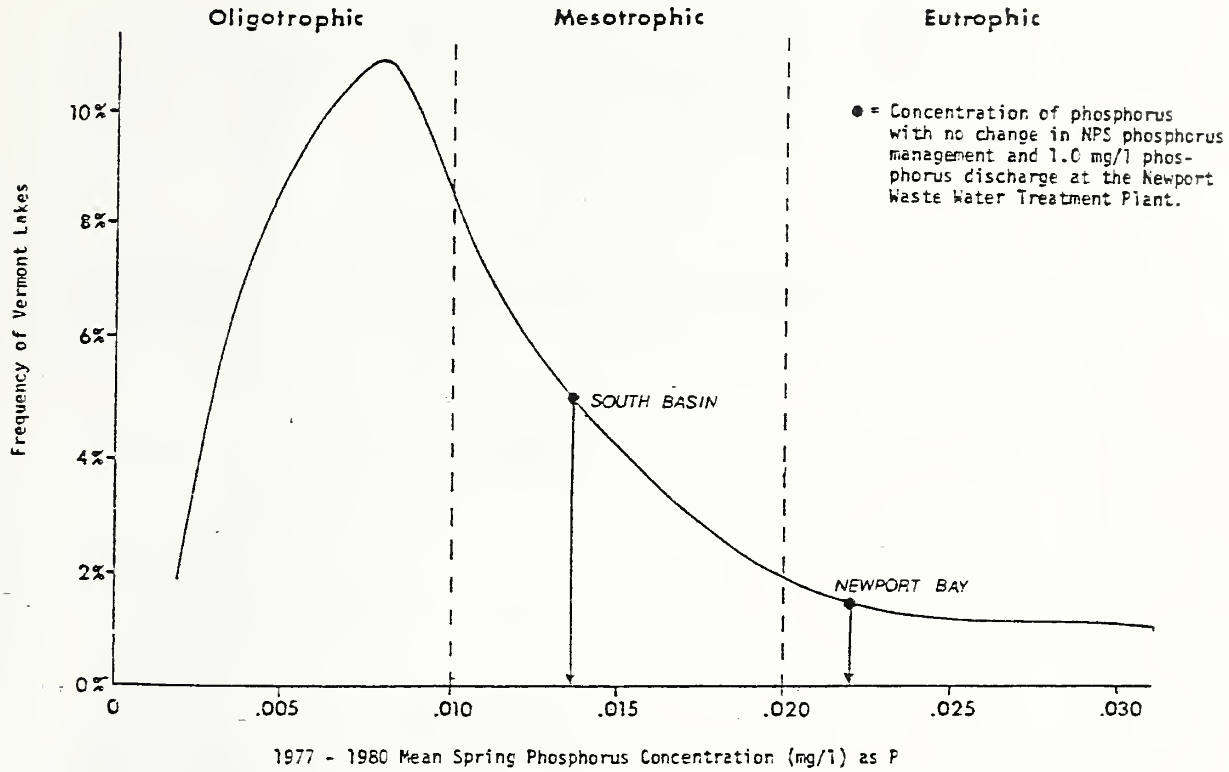
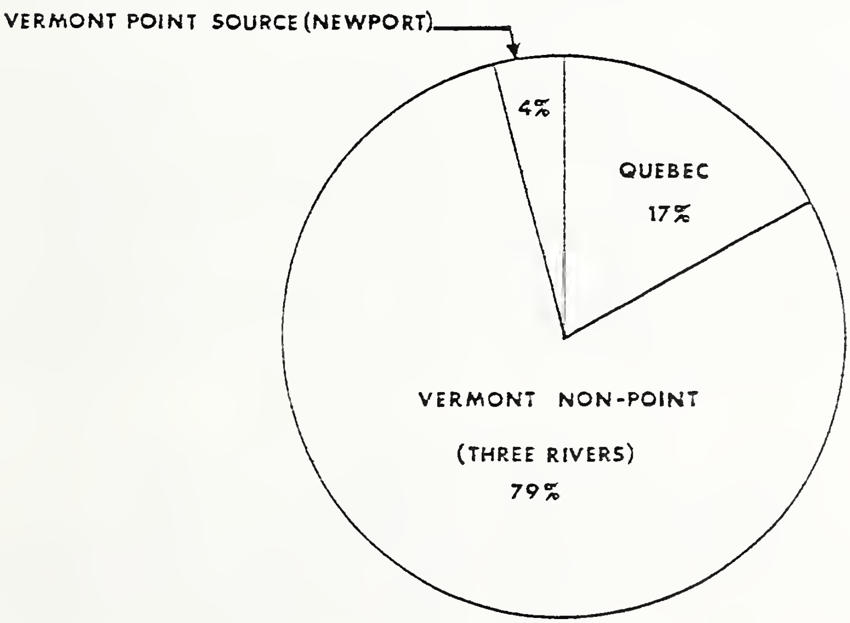


FIG. 3.4 SOURCES OF TOTAL PHOSPHORUS TO LAKE MEMPHREMAGOG*



*Estimated Values Following Completion of Newport Phosphorus Removal Facility, 1984.

Table 3.9 Estimated Total Phosphorus Load to Lake Memphremagog from Vermont

Sub-Basin	Watershed	(1) Acres	(2) All Total Phosphorus LBS	(3) All Total Phosphorus % of sub-basin	(4) Point Source (LBS)	(5) Non-Point Source LBS	(6) Non-Point Source % of (2)	(7) Agric (LBS)	(8) Agric-% of (5)	(9) Forest (LBS)	(10) Forest % of (5)
			Values Expressed in Terms of Estimated Annual Total Phosphorus								
PRIOR TO 1984											
	Black River	85,800	28,010	48	11,990	16,020	57	14,025	88	1,730	11
	Barton River (2)	101,260	12,740	22	0	12,740	100	9,720	76	2,420	19
	Clyde River (1)	88,120	11,510	20	0	11,510	100	7,735	67	2,680	23
	Direct Drainage	21,460	6,470	10	0	6,470	100	2,480	38	280	4
Total Vermont Drainage		296,640	58,730	100	11,990	46,740	80	33,960	73	7,110	15
Estimate by Carlson Kalff and Leggett 1/			45,744	100	13,759	31,985					
Adjustment Ratio 2/			.78		1.15	.68					
1984 AND BEYOND 3/											
	Black River		18,450	38	2,430	16,020	87	14,025	88	1,730	11
	Barton River (2)		12,740	26	0	12,740	100	9,720	76	2,420	19
	Clyde River (1)		11,510	23	0	11,510	100	7,735	67	2,680	23
	Direct Drainage		6,470	13	0	6,470	100	2,480	38	280	4
Total Vermont Drainage (Surrogate)			49,170	100	2,430	46,745	95	33,960	73	7,110	15
Estimate by Carlson, Kalff and Leggett 1/			36,192	100	4,207	31,985					
Adjustment Ratio 2/			.74		1.73	.68					

1/ The phosphorus and nitrogen budgets of Lake Memphremagog (Quebec-Vermont); with a predictive model of its nutrient concentration following sewage removal. R.E. Carlson, J. Kalff, W.C. Leggett, McGill University, March 1979.

2/ Adjustment ratio equals McGill ÷ Surrogate.

3/ Values valid after 1984, when P removal facility at Newport becomes operational.

Source: Agriculture and forest land - this study; other loads from unit values in (Loehr, 1974) and from estimates provided by Vermont Department of Water Resources and Environmental Engineering.

Table 3.9 provides annual total phosphorus load estimates to Lake Memphremagog from Vermont for both conditions -- that prior to completion of the Newport wastewater treatment plant in 1984 and that after 1984.

Harvey's Lake

Harvey's Lake is located in southern Caledonia County and outlets directly to the Connecticut River via the Stevens River (see Map 3.8). The lake's morphometric characteristics are shown in Table 3.10.

Table 3.10. Summary of Physical and Chemical Characteristics, Harvey's Lake

Surface area (ac.)	410
Volume (ac.-ft.)	23,430
Maximum depth (ft.)	145
Mean depth (ft.)	67
Retention time (yrs.)	2.0
Mean spring phosphorus (mg/l)	.012

The lake suffered from oxygen deficits in the hypolimnia and large meta and hypolimnetic algal populations in recent years. This problem is somewhat unusual compared to Champlain and Memphremagog because the surface waters are not infested with algal or weed populations. Spring phosphorus concentrations observed between 1977 and 1980 have increased 50 percent from 0.010 to 0.015 mg/l.

The average annual phosphorus loadings from the watershed for nonpoint sources are estimated by land use as shown in Table 3.11. The loadings shown include both Jewett Brook and South Peacham Brook inflows. South Peacham Brook does not flow directly into Harvey's Lake. Its phosphorus loads only partially enter the lake during periods of high flows. The Vermont Department of Water Resources has determined that the average annual phosphorus load to Harvey's Lake is 470 pounds (Smeltzer, 1983). An implementation plan should revise the values of Table 3.11 to more closely reflect values actually entering Harvey's Lake.

Shelburne Pond

Shelburne Pond is located in west central Chittenden County and drains via Muddy Brook into the Winooski River (see Map 3.9). Some of its morphologic characteristics are shown in Table 3.12.

Table 3.11. Estimated Land Use and Average Annual Total Phosphorus Values for Harvey's Lake Watershed (19)1/

Land Use	Area of Land Use	Total Phosphorus	Phosphorus as Percent of Total
	(acres)		
Agriculture	1,960	3,438	89%
Forestland	9,840	305	8
Urban	50	50	1
Water	500	20	1
Wetlands	220	9	1
Other	400	40	1
Total	12,970	3,862	100%

1/ This table should not be used as estimates for Harvey's Lake. See text.

Source: Agriculture and forest land -- this study; other estimates by unit values in (Loehr, 1974).

Table 3.12. Summary of Physical and Chemical Characteristics, Shelburne Pond

Surface area (ac.)	450
Volume (ac.-ft.)	5,326
Maximum depth (ft.)	26
Mean depth (ft.)	12
Retention time (yrs.)	0.78
Mean spring phosphorus (mg/l)	0.127

Large portions of the pond are covered by dense submergent and floating vegetation although severe turbidity caused by frequent algal blooms tends to control this weed growth. Shelburne is one of the most eutrophic water bodies in the state. It is naturally eutrophic and future attempts to reverse this condition are not recommended.

Spring phosphorus concentrations which have been observed over the period 1977-1980 have been extremely high, ranging from 0.147 to 0.099 with a mean of 0.127 mg/l. The pond's average annual phosphorus load from nonpoint sources estimated by land use is shown in Table 3.13. There are no significant point source loads.

Table 3.13. Land Use and Estimated Average Annual Phosphorus Load for Shelburne Pond Watershed (18)

Land Use	Area of Land Use	Total Phosphorus	Phosphorus as Percent of Total
	acres	pounds	
Agriculture	1,550	994	81%
Forestland	1,270	40	3
Urban	20	20	2
Water	500	20	2
Wetlands	310	12	1
Other	1,310	131	11
Total	4,960	1,217	100%

Source: Agriculture and forest land -- this study; other loads from unit values in (Loehr, 1974).

WHAT ABOUT 20 YEARS FROM NOW?

All the water quality management areas covered in this study will continue to decline in quality unless management steps are taken to slow eutrophication. Towns and municipalities will continue to upgrade waste water treatment facilities in cooperation with the Vermont Department of Water Resources and Environmental Engineering. Population growth will offset some of these pollutant reductions. Estimates of changes in point source phosphorus loads to each of the WQMA's are listed in Table 3.14.

Phosphorus loads from agriculture will decline slightly because of ongoing USDA programs such as the Agricultural Conservation Program. Soil erosion will remain essentially constant over the years because gains in erosion control on participating farms will be offset by losses from preferred management on other farms. Gains in phosphorus management from ongoing agricultural programs will be realized primarily from improved agricultural waste management. Estimates of changes in agricultural nonpoint source phosphohrus loads to the WQMA's are also listed in Table 3.14.

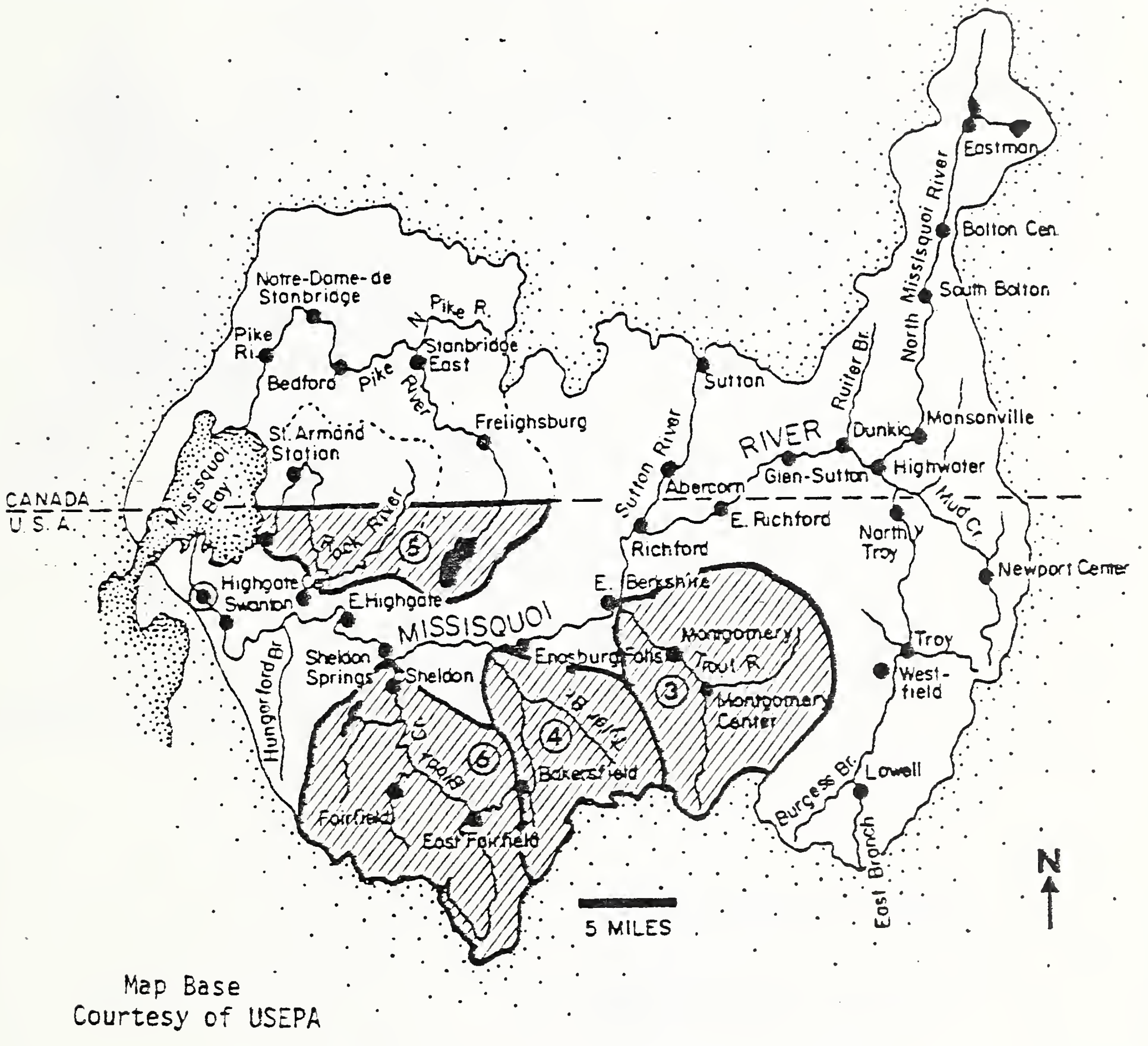
Table 3.14. Estimates of Mean Total Phosphorus Loads to WQMA's, 2000

WQMA	Point Source	Nonpoint Source Agriculture	Nonpoint Source Other	Total
	Pounds of total phosphorus			
Missisquoi Bay	92,470	173,640	19,990	286,100
Mallets Bay	51,890	53,210	18,320	123,420
Central Main Lake	277,090	55,100	71,320	403,510
South Main Lake	103,880	286,010	53,830	443,720
South Lake	19,180	55,770	9,290	84,240
Lake Memphremagog	7,310	32,050	12,780	52,140
Harvey's Lake 1/	50	2,800	370	3,220
Shelburne Pond	20	750	200	970

1/ Values provided for Harvey's Lake apply to the entire watershed. Inflows to Harvey's Lake would be lower.

Source: Agriculture and forest land -- this study; other loads estimated using unit values from (Loehr, 1974) and values provided by Vermont Department of Water Resources and Environmental Engineering.

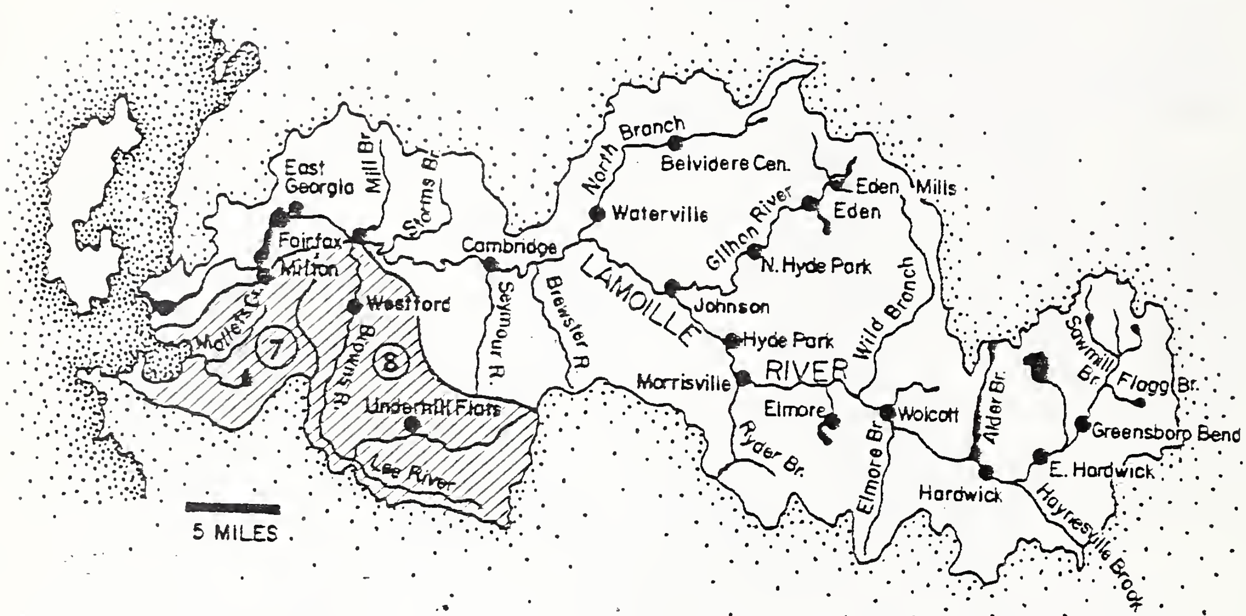
Map 3.2 The Missisquoi Bay Subbasin of Lake Champlain



Map Base
Courtesy of USEPA

Shaded portions are
watersheds evaluated
as a part of this study

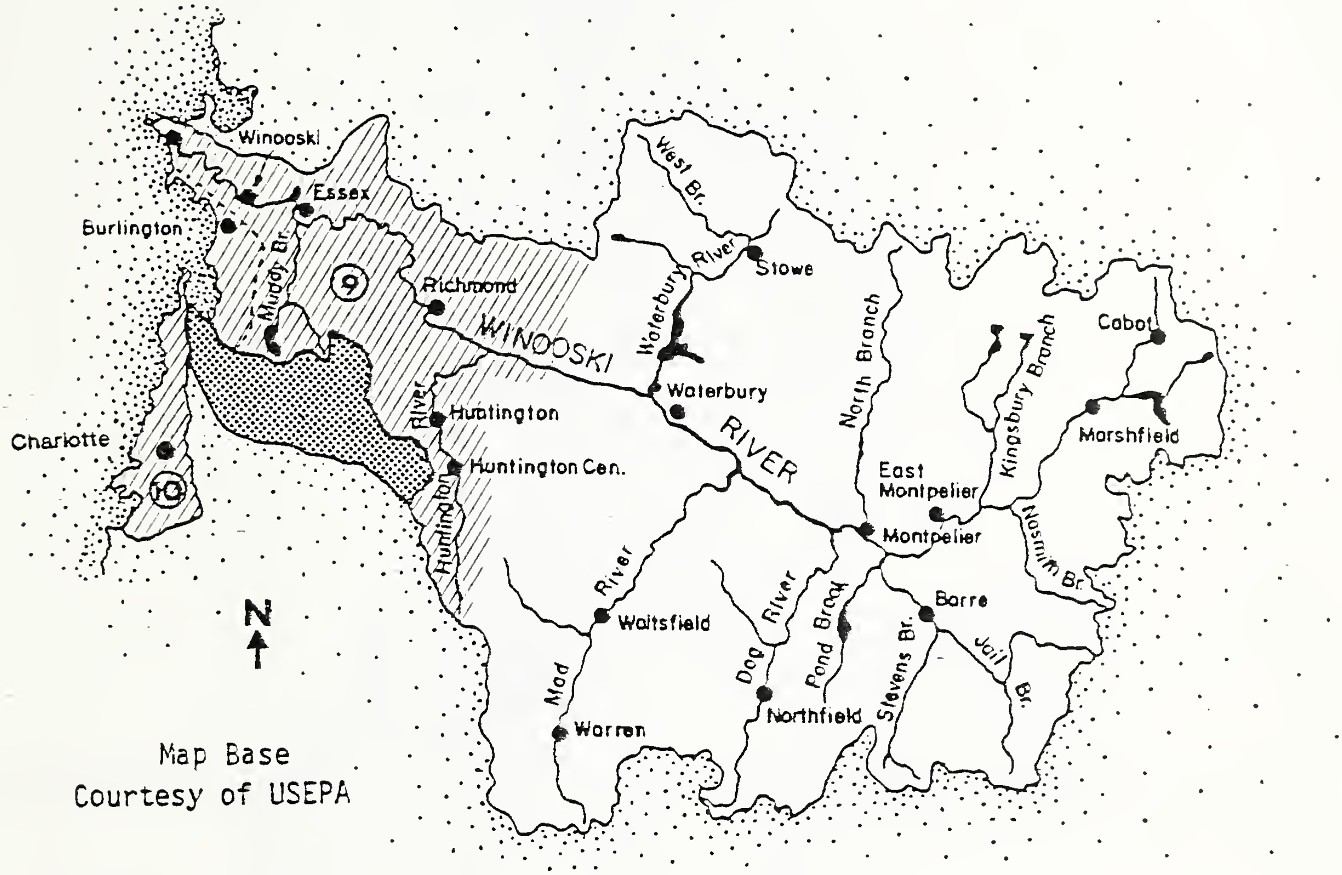
Map 3.3 Malletts Bay Subbasin of Lake Champlain



Map Base
Courtesy of USEPA

Shaded portions are watersheds evaluated as a part of this study.

Map 3.4 Vermont Portion of Central Lake Champlain Subbasin

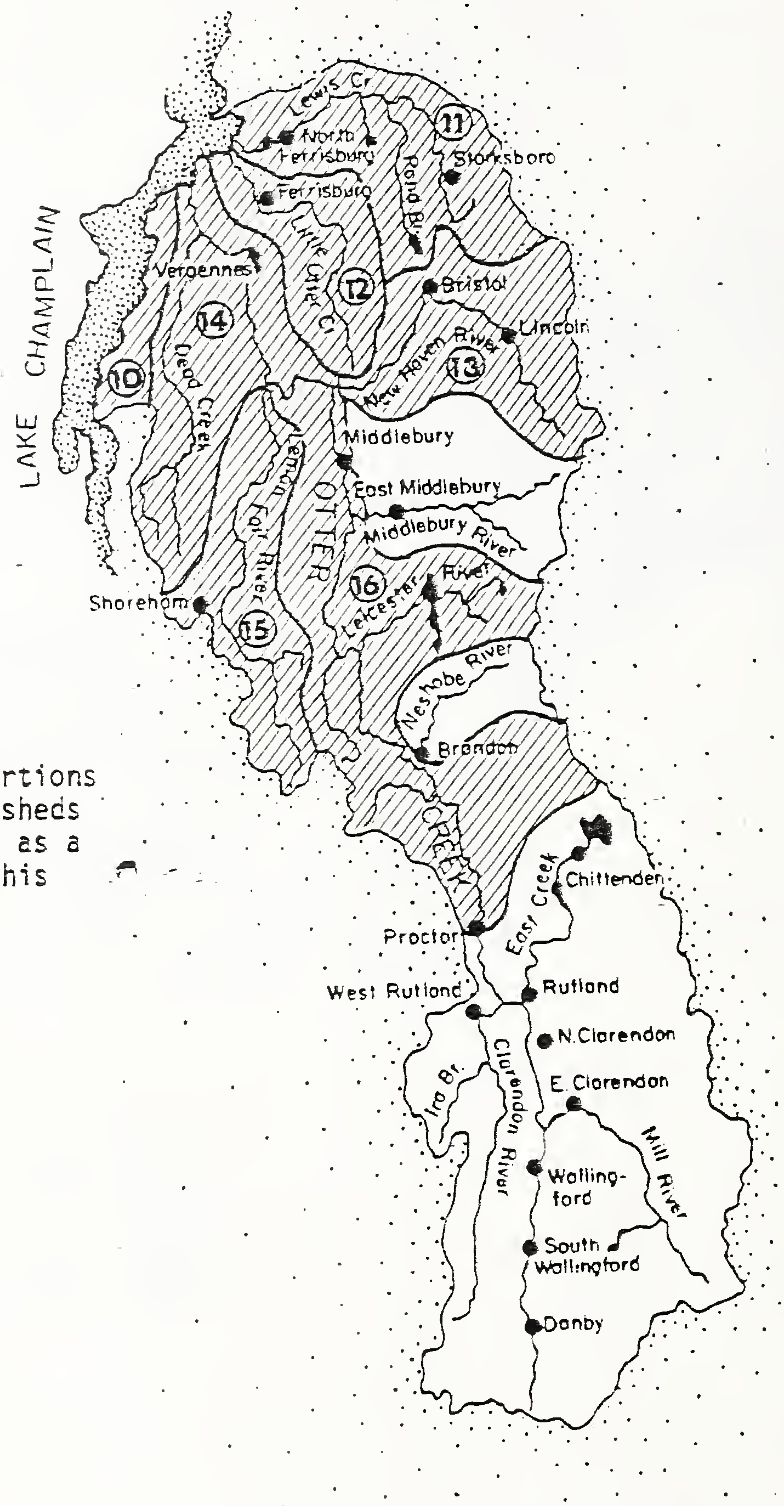


Map Base
Courtesy of USEPA

Watersheds evaluated as a part of this study.

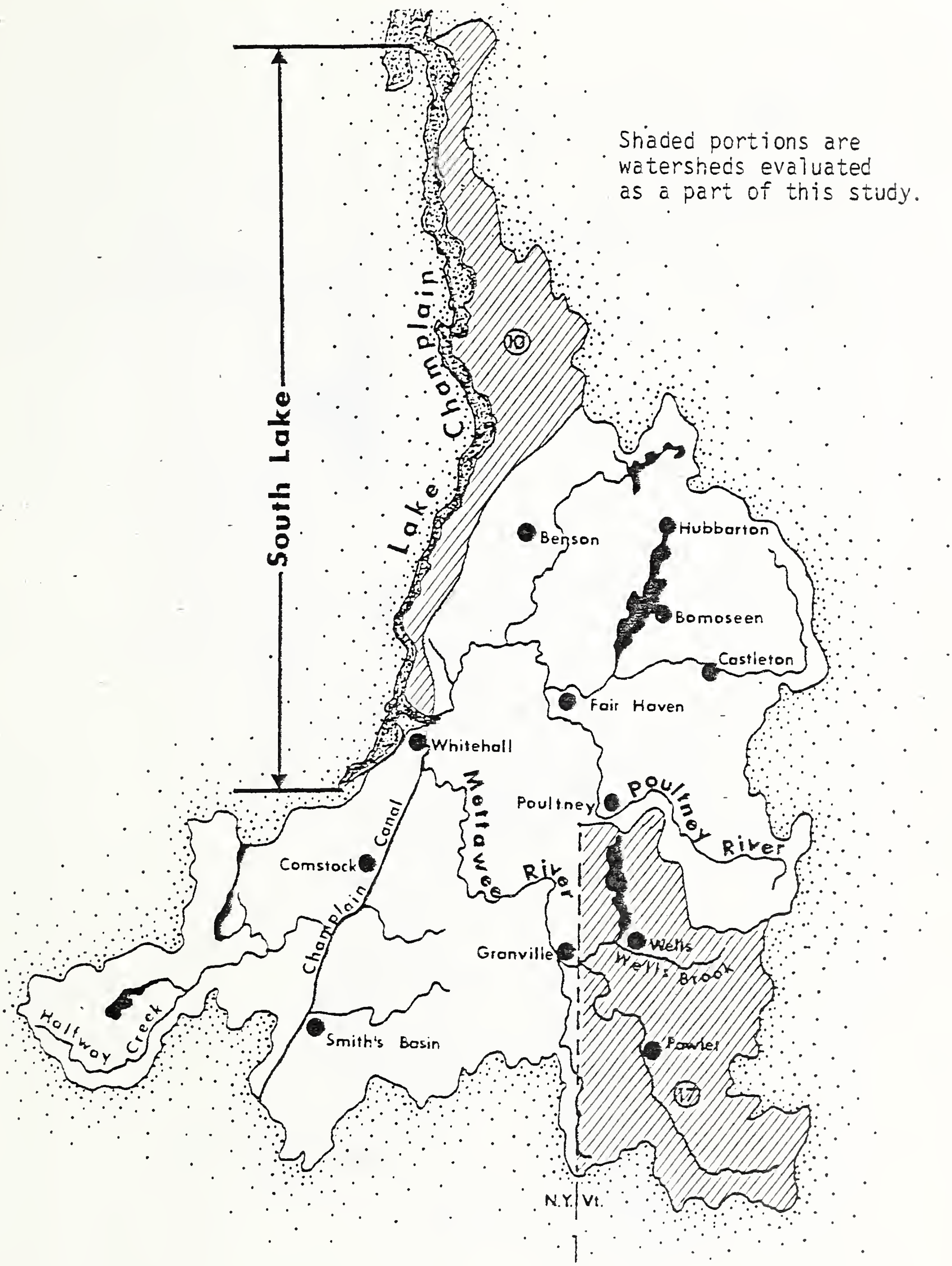
Laplatte Watershed PL 566 Project.

Map 3.5 Principal Drainages to the South Main Lake Champlain Basin

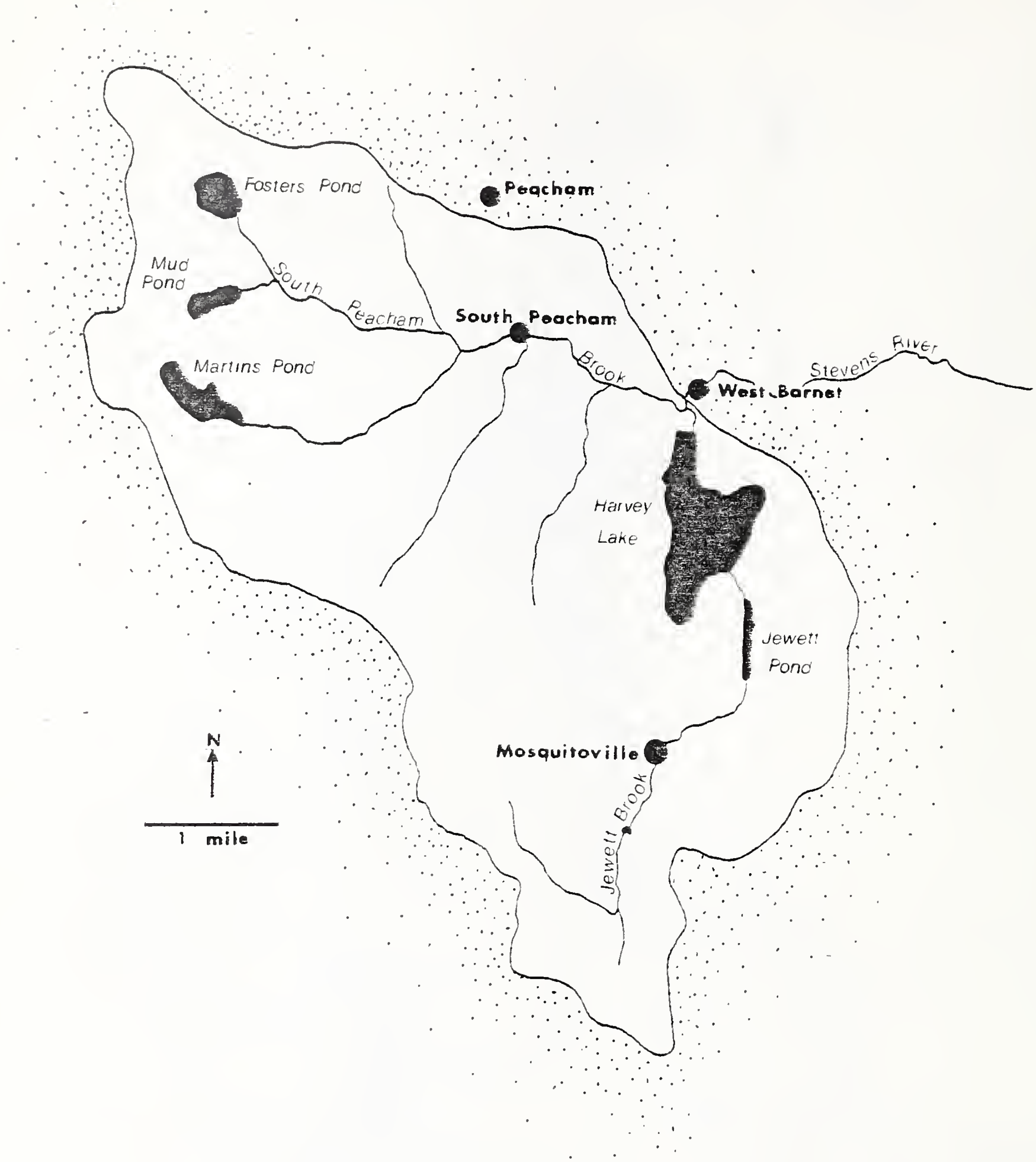


Shaded portions are watersheds evaluated as a part of this study.

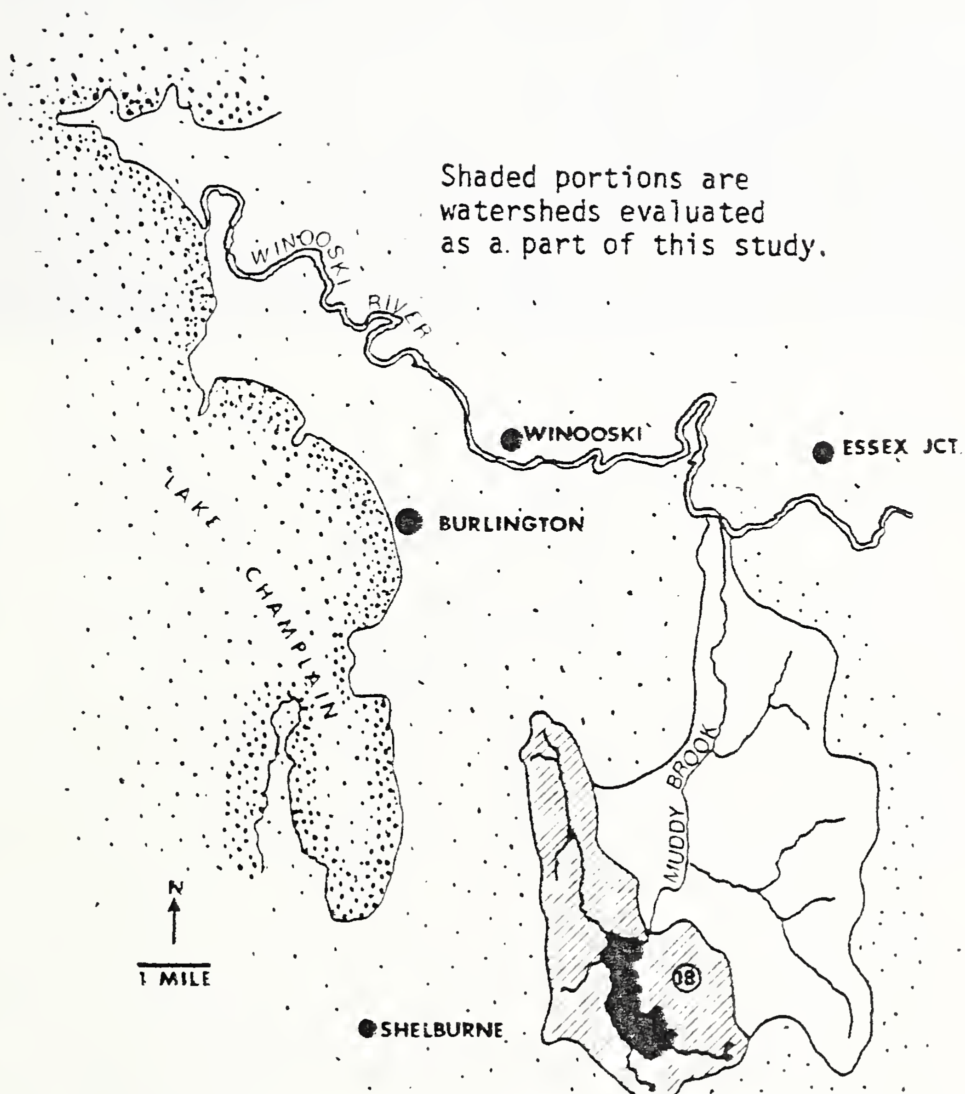
Map 3.6 Vermont Drainage to the South Lake, Lake Champlain



Map 3.8 —Harveys Lake Drainage



Map 3.9 Shelburne Pond Drainage



CHAPTER 4

CLEAN WATER THREATS FROM LAND RUNOFF

SUMMARY OF PHOSPHORUS SOURCES

Chapter 3 provided phosphorus loading values for the various water quality management areas (WQMA's) of Lake Champlain, Lake Memphremagog, Harvey's Lake and Shelburne Pond. These are summarized briefly in Table 4.1. They represent only the Vermont contributions to Lake Champlain and Lake Memphremagog (Missisquoi Bay values include Canadian sources). Expressed in terms of total nonpoint source loads, however, Vermont contributions of total phosphorus to Lake Champlain and Lake Memphremagog are 59 percent and 68 percent, respectively.

Figure 4.1 shows the significance of agricultural nonpoint source phosphorus to total loads in each of the four lakes receiving runoff from watersheds of this study.

This summary shows that agriculture is the single largest source of total phosphorus load to each of the water quality management areas receiving runoff from the study watersheds. It also shows that forest source phosphorus is significant, particularly in the Lake Memphremagog and Harvey's Lake drainages. Clearly these nonpoint sources are significant. They are described in more detail in this chapter.

AGRICULTURAL SOURCES OF PHOSPHORUS

Vermont Farming

Dairy farming is the primary agricultural endeavor in Vermont and is also responsible for the largest contributions of agricultural nonpoint source nutrient loadings to water courses. Figure 4.2 shows the relationship of dairy livestock to other livestock and poultry in terms of estimated manure production in Vermont. Because crop production, where the majority of Vermont's soil loss occurs, is directly correlated with manure production, most agricultural nonpoint source phosphorus can be controlled by concentrating management improvement activities on the dairy farms.

Controllable Dairy Farm Sources of Phosphorus

Phosphorus loadings originate from five basic sources on dairy farms, namely: field spread manure, barnyards, manure stacks, milkhouses, and soil erosion. In some cases silage effluent may also be a phosphorus source; however, little research has been done on this subject. Consequently, it was not considered in this study. The discussion below explores the mechanisms and variables associated with phosphorus runoff from the five farm sources listed above.

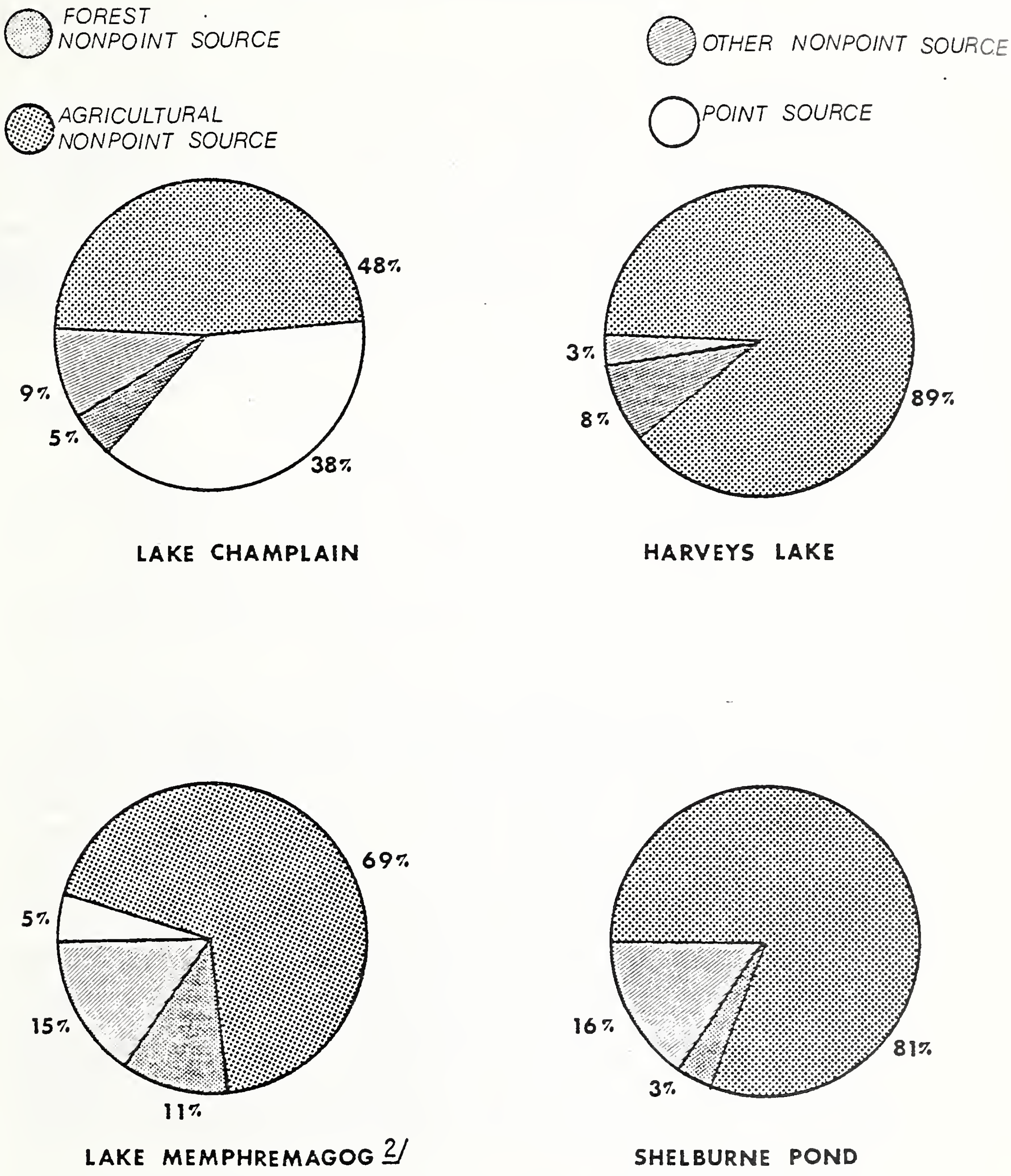
Table 4.1 Summary of Estimated Average Annual Total Phosphorus Loads from Vermont to Principal Water Quality Management Areas in the Study

Water Quality Management Area	Total 2/ Phosphorus	Non Point Source Phosphorus	Percent of Total	Non Point Source Loads and Percent of Total NPS											
				Agriculture lbs	%	Forest lbs	%	Urban lbs	%	Water lbs	%	Wetlands lbs	%	Other lbs	%
Lake Champlain-All Vt 1/	1,343,520	832,310	62	656,125	79	63,735	8	73,600	9	2,240	<1	2,240	<1	33,970	4
Missisquoi Bay	277,650	197,460	71	177,460	90	13,910	7	4,170	2	730	<1	780	<1	410	<1
Northeast Arm	62,400	13,100	21	7,340	56	260	2	5,500	42	-		-		-	
Mallets Bay	102,060	71,320	73	53,455	75	12,765	18	2,070	3	400	<1	100	<1	2,530	3
Central Main Lake	369,900	126,050	34	54,690	44	15,010	12	44,500	35	600	<1	890	1	10,360	8
South Main Lake	420,750	329,890	79	277,490	85	16,050	5	14,500	4	310	<1	870	<1	20,670	6
South Lake	110,760	94,490	85	85,690	91	5,740	6	2,860	4	200	<1	-		-	
Lake Memphremagog (U.S.)	58,730	46,740		33,960	73	7,110	15	4,610	10	350	<1	90	1	620	1
Harvey's Lake Watershed 3/	3,860	3,860		3,440	89	305	8	50	1	20	1	5	<1	40	1
Shelburne Pond	1,220	1,220		990	81	40	3	20	2	20	2	10	1	140	11

1/ Missisquoi Bay includes Canadian portion as well as Vermont
2/ Includes point source values provided by Vermont Department of Water Resources and Environmental Engineering
3/ Values listed are for entire watershed. Values for loads to Harveys Lake will be considerably lower because of South Peacham Brook bypass and need further work for reasonable estimates.

Source: Agriculture and forests - this study; other loads from unit values in (Loehr, 1974) and from Vermont Department of Water Resources and Environmental Engineering.

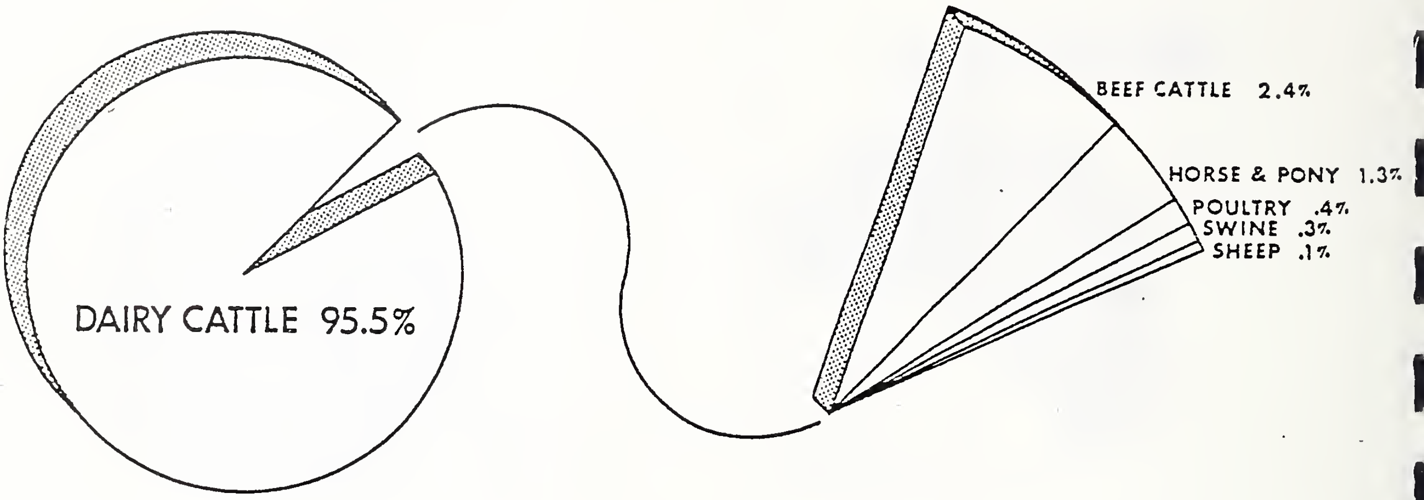
Figure 4.1 Relationship of Agriculture to Total Phosphorus Loads from Vermont by Receiving Lakes



1/ Total phosphorus loads are from Vermont drainage only except for contributions to Missisquoi Bay of Lake Champlain.

2/ Values valid after 1984, when P removal facility at Newport becomes operational.

Fig. 4.2 Relationship of Various Livestock to Total Animal Waste Production in Vermont (Estimated from Census Data)



Field Spread Manure

Phosphorus losses derived from animal manures typically occur through runoff from field spread manure, manure stacks, and barnyards. Snow covered fields on which manure has been applied melt during a relatively short period of time in late winter or early spring, generally when soils are still frozen. Consequently, concentrated runoff is effectively precluded from infiltrating into the soil profile. This allows significant amounts of dissolved phosphorus and other manure constituents such as organic matter, nitrogen, and microorganisms to enter water courses, often coloring them dark brown. Phosphorus losses from manured fields occur with spring, summer, and fall applications as well, particularly when manure is not incorporated. However, losses at other seasons are lower than from winter spreading. Cropping patterns influence the amount of dissolved phosphorus that may run off agricultural fields. Farms with feeding programs consisting of only hay have limited opportunity to incorporate manure, thus increasing the risk of phosphorus losses from surface runoff.

Reducing phosphorus loadings from field spread manure requires careful management on the part of the farmer. Storage, proper timing of application, and incorporation of animal waste are the key elements in minimizing manure-derived nutrient loadings to water courses. Storage of animal waste in either earthen pits or sealed storage allows the farmer to break out of the daily spread routine and

distribute animal waste at times of the year in which losses of soluble nutrients are minimized.

The impacts of field spread manure on water quality depend on season applied and whether manure is incorporated. Of equal influence, however, is the proximity of water courses to manured fields and the nature of intervening vegetation. Research indicates phosphorus attenuation to background levels over a "critical distance" found to be between 100 and 400 feet (Draper and Robinson, 1978). The 400 foot critical distance is used in this study to determine the delivery ratio of phosphorus from stacks, barnyards and milkhouse waste (SCS, 1982). Application of manure to fields bordering water courses, especially when vegetation is absent or in poor condition, increases concentrated phosphorus loads.

Barnyards

Barnyards in which stacking occurs or animal densities are high can contribute significant amounts of dissolved phosphorus to runoff. Barnyard problems are unique to each farm and specific site characteristics. Generally, however, problem barnyards are often characterized by: (1) area completely open; (2) manure allowed to accumulate or scraped into uncovered piles; (3) water from uphill sources runs through the lot area; and (4) animals are confined to the area for considerable periods of time (Moore, Madison and Schneider, 1978).

The severity of the problem is correlated with the distance to a water course. Barnyards characterized by the problems mentioned above may cause management headaches but are little threat to water quality if there is sufficient vegetation between the barnyard and the nearest water course.

Manure Stacks

Stacking manure can provide dissolved phosphorus loadings to nearby water courses. The method used is essentially the same throughout the state, consisting of stacking manure in the barnyard or hauling manure to nearby fields and piling where access is convenient. Three factors control the effect stacking will have on water quality to a large degree: (1) location of stack; (2) distance to nearest water course; and (3) nature of intervening ground cover between stacks and water course. Stacks located in flood plains can result in virtually complete dispersal of manure-derived nutrients in flood waters. The distance to nearest water course influences the quantity of stack runoff which enters water courses through delivery ratio reductions (SCS, 1982).

Milkhouse Waste

Milkhouse waste provides another on-farm source of phosphorus loadings. This waste originates from several sources on dairy farms including milk pipelines, milking parlors, holding areas, and the milkroom. Human wastes may also be generated; however, these wastes should be handled by a system separate from the animal waste. Effluent from milkhouses is commonly composed of a combination of waste milk, antibiotics, detergents, cleaners and sanitizers. In addition milking parlors contribute manure, waste feed and dilute disinfectant. Farms without management systems commonly straight pipe milkhouse effluent to a nearby ditch or stream.

Cropland Erosion

Soils are defined by some as "rocks on the way to the sea." This rather poetic definition embraces a very important and fundamental characteristic of soils; their ability to be moved. This movement of soil on the landscape is termed erosion. Soil erosion or detachment occurs when wind and water forces exerted upon soil particles exceed forces resisting movement.

Phosphorus, applied as commercial fertilizer, manure and from breakdown of phosphorus-bearing minerals, binds tightly to soil particles. Although erosion is a normal geologic process, rates exceeding the capability of soils to regenerate result in a net depletion of the resource base. This accelerated erosion results in increased turbidity of streams and deposition of phosphorus-enriched sediments in receiving waters.

Erosion on Vermont soils occurs predominantly on cornland during early spring and again in late fall. In spring and early summer, sufficient crop canopy has not been established to break raindrop energy and reduce the erosive capacity of rainstorms. In the case of corn silage, for which most Vermont corn is used, fall harvesting removes the entire crop leaving bare soil vulnerable to erosive forces. Along with the effects of the cropping system, other factors influence the degree of erosion, including slope, soil type, local climate conditions and farming practices. Only three of these factors: cropping system; slope length; and farming practices can be readily adjusted through planning efforts to reduce soil erosion. See Technical Report No. 1 (SCS, 1982).

Inherent soil characteristics determine the maximum rate at which a soil can erode and still sustain crop production in an economic fashion. This maximum rate is termed the "soil loss tolerance" or "T" value and differs for each individual soil type. When erosion exceeds the regenerative capacity of the soil, the ability of that soil to provide a fertile and responsive medium for plant growth diminishes. If severe erosion continues unabated, the soil may be depleted to such an extent that only nonagricultural species may survive. Reducing

erosion as close to the tolerance level as possible is a planning goal which reduces soil-derived phosphorus and simultaneously preserves the soil resource base. The benefits from achieving this goal must be weighed against the costs of achieving it. As shown in Table 4.2, the majority of soil erosion in the Champlain, Memphremagog and Harvey's Lake basins occurs above the soil tolerance levels. In the Champlain basin, 87 percent of the delivered sediment and adsorbed phosphorus is derived from 35 percent of the cropland eroding above the tolerance level. In the Memphremagog basin, the percentage is somewhat lower with 77 percent of delivered sediment and adsorbed phosphorus lost from 7 percent of the cropland exceeding the erosion tolerance level.

Table 4.2. Erosion, Sediment Yield and Adsorbed Phosphorus Loss from Cropland in the Champlain and Memphremagog Basins

Basin	From Land Eroding: At All Rates	From Land Eroding: Above Tolerance Level	Above Tolerance as Percent of Total
Lake Champlain			
Erosion (tons/yr.)	663,000	576,000	87
Sediment (tons/yr.)	97,900	85,000	87
Adsorbed phosphorus (pounds/yr.)	267,000	232,000	86
Lake Memphremagog			
Erosion (tons/yr.)	26,000	20,000	77
Sediment (tons/yr.)	2,900	2,200	76
Adsorbed phosphorus (pounds/yr.)	8,300	6,300	76

SILVICULTURAL SOURCES OF PHOSPHORUS

Phosphorus runoff from forest land is the second most significant nonpoint source of phosphorus in seven of the nine water quality management areas of the study. Urban nonpoint sources are far more significant to the other two WQMA's. Forest sources are, then, important for management consideration.

Vermont Forestry

Over 70 percent of Vermont is forested today. Within the study watersheds, percent forest varies greatly from a low of 24 percent for watershed 14 in the Champlain Lowlands to a high of 91 percent for watershed 3 in the Green Mountains. Forest land has been on the

increase statewide for many years, primarily because of abandonment of farmland.

Maple beech-yellow birch (northern hardwood) is the predominant Vermont forest type. Hemlock, white pine, basswood and white birch are also frequently found in the moist portions of these normally well-drained stands. Early successional species such as white pine, eastern red cedar, aspen, white birch, gray birch, pin cherry and red maple often become first established on abandoned farmland.

Elm, ash and red maple normally occupy wet areas and lowlands. Northern white cedar are frequently found in swampy and limestone areas.

The most productive forest sites are generally found below elevation 1500 where the soils are deeper and the growing season is longer. There are vast amounts of land above elevation 1500 which are mostly forested, have shallow soils and are particularly sensitive to disturbances such as timber harvesting operations.

Forest land ownership throughout the study watersheds is mostly private and is generally held in tracts under 500 acres in size. There are scattered larger tracts primarily under state and National Forest ownership.

Timber harvest activities generally cycle about once each forty years. Most harvested hardwoods are used for furniture, veneer and utensils, while softwoods provide construction lumber, plywood and pulp. With the advent of woodburning as a significant source of residential heating in Vermont, more frequent harvesting is now occurring to remove culls and undesirable species for firewood. In Burlington a 50 megawatt wood-fired generation plant to use 400,000 tons of wood annually is expected to go into operation in late 1983 as an added wood consumer. All of these activities stress forest land soils, particularly where skid trails and roads, yards and haul roads are established.

Controllable Forest Sources

Phosphorus yields from forested areas are derived primarily from soil erosion. Undisturbed forests throughout the East erode at a rate of from .05 to .10 tons per acre per year. Considering delivery rates to streams, undisturbed areas, then, contribute about .03 pounds of phosphorus per acre per year. There are no practical means of reducing these undisturbed yields.

Harvesting activities accelerate soil erosion where the logs are transported through the forest and off the site. Activities which remove forest litter and expose the bare soil increase soil erosion. Felling of trees has no appreciable effect. Skid trails, skid roads, landings and haul roads cause the bulk of accelerated erosion.

Erosion rates from these disturbances vary from a low of 0.1 tons per acre per year to a high of 129 tons per acre per year (see Technical Report No. 4). This amounts to phosphorus yields of from .03 pounds to 43 pounds entering the streams each year. Table 4.3 provides the average annual erosion rates on roads and landings by watershed.

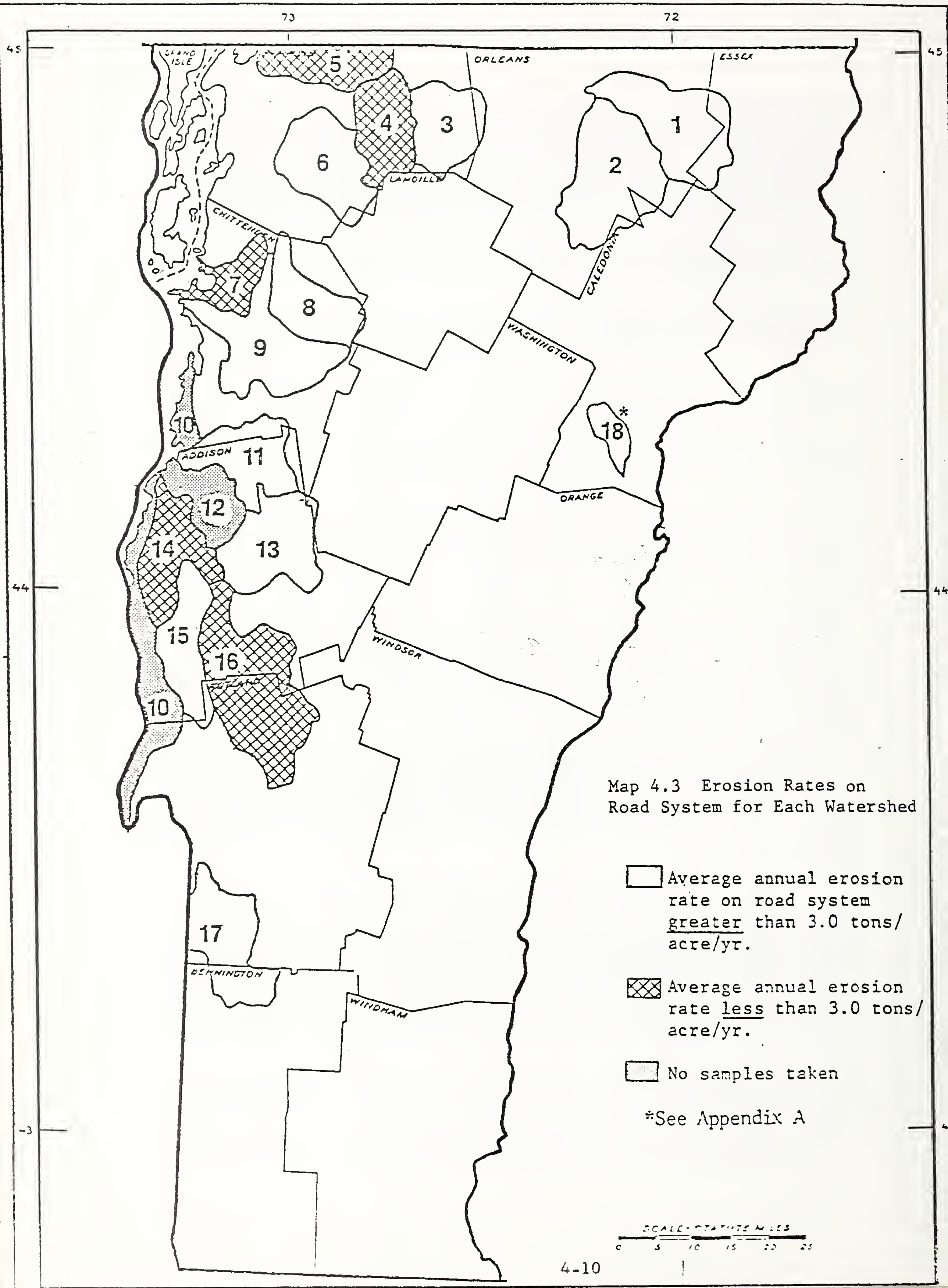
Table 4.3. Average Annual Erosion Rates on Roads and Landings by Watershed

Watershed Number	No. of Sample Pts.	A (t/ac/y)	Std. Dev.	Low (t/ac/yr)	High (t/ac/yr)
1	63	6.5	13.52	0.0	78.8
2	63	10.6	23.23	0.0	129.3
3	21	15.2	19.80	0.5	69.1
4	21	2.3	3.14	0.0	9.9
5	16	0.6	1.11	0.0	4.5
6	31	5.9	13.45	0.0	65.8
7	21	1.0	2.16	0.0	10.1
8	18	3.9	4.52	0.0	17.1
9	37	9.5	24.79	0.0	121.4
11	16	8.0	7.91	0.3	26.4
13	23	8.6	11.72	0.2	34.2
14	9	0.2	0.24	0.1	0.5
15	20	6.0	7.70	0.1	32.5
16	31	2.9	3.60	0.1	12.1
17	85	7.8	17.06	0.0	93.0

Distribution of accelerated forest land erosion is readily apparent in Map 4.3. Those flatter watersheds adjacent to Lake Champlain in the Champlain Lowlands have generally low average annual erosion rates whereas steeper watersheds along the edge of the Green Mountains and in the Vermont Piedmont have higher erosion rates. Slope is an important factor.

Harvest operations can be controlled to reduce the erosion. Analysis of various levels of technical assistance provided to harvesting operations showed a reduction of over 50 percent in average annual road and landing erosion when best management practices are applied. Phosphorus yields could be reduced by the same proportion. Forest land contributions of phosphorus to each of the water quality management areas are provided in the Quantification and Summary section of this chapter.

VERMONT



Map 4.3 Erosion Rates on Road System for Each Watershed

BACKGROUND PHOSPHORUS SOURCES

There are several sources of phosphorus in the watersheds which cannot be significantly reduced through conservation practices applied to agricultural and silvicultural land. These sources will continue to supply a base loading of phosphorus to the waterways regardless of whether or not any of the plans presented in this report are implemented.

The manure dropped randomly by grazing livestock and wildlife on pastureland is a source of phosphorus that is not addressed in this study. Short of ceasing to graze livestock, there is no effective way of reducing this base loading.

Phosphorus is available to a limited extent from decaying organic matter. Decaying organic matter is the base source of phosphorus from pastures, forests and idle land. Although this source is not significant on a per acre basis (.03 lb/ac/yr--forest land and .10 lb/ac/yr --pasture/idle land), it is significant at the watershed level since a high percentage of total land in the watersheds is forested or idle land.

In times of low flow, wetlands serve as sinks for phosphorus. Sediment, and associated adsorbed phosphorus, settles out in the slow-moving water and dissolved phosphorus is taken up by the abundant vegetation found in wetlands. However, wetlands do not dissipate phosphorus. They merely serve as a buffer, holding back the phosphorus until a time of high flow when silt and decaying vegetation is flushed through to other receiving waters.

Wetlands also serve as excellent habitat for wildlife. The waste materials from this wildlife are added to the wetlands, increasing the loading of phosphorus to be flushed through during times of high flow.

In addition to the point sources of phosphorus such as effluent from industries and sewage systems associated with urban developments, considerable nonpoint source phosphorus is also contributed to the waterways by urban areas. Such normal human activities as fertilizing lawns and gardens, washing cars and keeping domestic animals contribute to a reserve of phosphorus which washes off as direct runoff or through storm sewer systems during times of heavy rainfall. These activities contribute ten times the phosphorus (1.0 lb/ac/yr) as would be expected from the same land were it to remain idle.

Table 4.4 shows the estimated phosphorus yield from study watersheds in the Memphremagog and Champlain basins from the background sources described above.

Table 4.4. Background Phosphorus Sources

Land Use	Lake Champlain		Lake Memphremagog	
	Acres	Total P Pounds/Year	Acres	Total P Pounds/Year
Pasture/Idle	175,560	17,770	9,660	970
Forest	628,010	19,130	145,230	4,390
Wetlands	22,670	900	1,250	30
Urban	11,220	11,220	1,280	1,280

Source: Values derived from this study and from unit values in (Loehr, 1974).

QUANTIFICATION AND SUMMARY

Agriculture

This section examines the results of quantifying controllable nonpoint source phosphorus loads and explores the relationship between uncontrollable and controllable nonpoint agricultural phosphorus loads. Table 4.5 displays total nonpoint source phosphorus loadings and breaks out the agricultural portion by source. In addition, a comparison is made between controllable and total phosphorus. Annual basin-wide phosphorus loads from study areas in the Champlain and Memphremagog Basins, Harvey's Lake and Shelburne Pond watersheds are depicted in Table 4.6. Geographical distribution of phosphorus loads from study watersheds to water quality management areas is displayed in Table 4.7. Seasonal loadings of dissolved phosphorus from study watersheds to water quality management areas are shown in Table 4.8.

In assessing the potency of various phosphorus sources, the relationship between dissolved and adsorbed phases must be kept in mind. Barnyards, manure stacks, milkhouse waste and manured fields contribute dissolved phosphorus which is assumed to be all biologically available. Adsorbed phosphorus from soils is assumed to be 20 percent biologically available for algae and other aquatic plant growth (Lake, 1977). Pound for pound, the phosphorus loads from barnyards, manure stacks, milkhouse waste and manured fields are more nutritionally potent than loads from soil erosion.

The majority of agricultural nonpoint phosphorus is derived from sources which are amenable to best management practices. This category includes soil erosion, barnyards, manure stacks, milkhouse waste and manured fields. Because of their minor significance, phosphorus loads from pastures are assumed uncontrollable for purposes of this study. Table 4.5 displays the relationship of total nonpoint phosphorus with nonpoint agricultural loads.

The Lake Champlain study areas generate approximately 390,760 pounds of nonpoint source phosphorus. Agriculture accounts for 350,960 pounds, with 12,660 pounds derived from uncontrollable sources and 338,300 pounds from controllable sources. This 338,000 pounds, or 96 percent, of agriculturally derived phosphorus can be partially controlled through adoption of best management practices.

Study areas in the Memphremagog Basin contribute 24,250 pounds of agricultural nonpoint source phosphorus to South Bay. As in the Champlain Basin, a majority of the agricultural nonpoint phosphorus load, 16,700 pounds, or 96 percent of the total loading, is derived from controllable sources. An estimated 760 pounds is lost as uncontrollable phosphorus.

Harvey's Lake Watershed produces 3,860 pounds of nonpoint source phosphorus, of which 3,440 pounds is attributed to agriculture. Controllable sources constitute 98 percent of the total nonpoint agricultural load, or 3,360 pounds.

Shelburne Pond receives 1,220 pounds of nonpoint source phosphorus. Agriculture contributes 1,000 pounds of the total loading. Approximately 89 percent, or 890 pounds, is from sources subject to best management practices.

In the Champlain Basin watersheds, 79 percent of the total phosphorus (dissolved plus adsorbed) load is derived from soil erosion (see Table 4.6). However, soils contribute only 43 percent of the available load with barnyards, manure stacks, milkhouse waste and manured fields making up the remainder. Of these sources, manured fields and barnyards contribute the greatest share of dissolved phosphorus, 59,080 pounds or 82 percent.

In the Memphremagog Basin, adsorbed phosphorus loads from soil erosion play a relatively smaller role in overall nonpoint source agricultural loadings as compared with the Champlain Basin. Adsorbed phosphorus contributes half of the total phosphorus loads in the Memphremagog drainage. However, only 16 percent of the available phosphorus is derived from soil erosion. Barnyards and field spread manure provide most of the dissolved phosphorus.

Soil erosion appears to be the major source of agricultural nonpoint phosphorus loads to Harvey's Lake. Available phosphorus, however, appears to be split more evenly between the dissolved and adsorbed portions. Approximately 45 percent of available phosphorus is derived from animal waste and milkhouse effluent while soil erosion accounts for 55 percent of the available loading.

Dissolved phosphorus loads overwhelm adsorbed loads significantly in Shelburne Pond. In this case, 87 percent of available phosphorus is derived primarily from barnyards and field spread manure. Soil erosion provides the remaining 13 percent.

Table 4.5 Quantification of Nonpoint Source Pollutants by Major Drainage Basins 5/

	Total Nonpoint Phosphorus 1/	Agricultural Nonpoint Source Phosphorus: Cropland	Pasture	Barnyard	Milk-House	Manure Stacks	Uncontrollable Agricultural Nonpoint Phosphorus 2/	Controllable Agricultural Nonpoint Phosphorus 3/	Controllable as Percent of Total Agricultural Phosphorus 4/	Erosion: Crop-Land	Forest-Land	Sediment: Cropland & Forest Land	Animal Waste Systems Needed: Manure Storage	Barn Yards	Milk House
	Pounds								Percent	Tons per Year			Number		
Champlain	390,760	302,350	12,660	24,070	9,200	2,780	12,660	338,300	96	663,430	65,410	117,420	489	446	312
Memphremagog	24,250	11,830	760	3,540	350	980	760	16,700	96	25,990	15,385	7,440	42	101	69
Harveys Lake	3,860	3,080	80	180	90	20	80	3,360	98	4,690	1,020	1,250	9	7	9
Shelburne Pond	1,220	640	110	180	70	0	110	890	89	670	130	190	4	2	1

1/ Sum of phosphorus from forest land and roads, water, wetlands, urban, cropland, pasture, barnyards, milkhouse, manure stacks, and other, estimated as yields from study watersheds only.
2/ Nonpoint source phosphorus loads from pastures only.
3/ Sum of agricultural nonpoint source phosphorus from cropland, barnyards, milkhouses, and manure stacks.
4/ Percent equals sum of uncontrollable and controllable agricultural nonpoint phosphorus divided by the controllable portion.
5/ Study portions only.

Table 4.6 Sources of Annual Phosophorus Loads from Agriculture Showing the Availability of Phosphorus from Study Areas in the Champlain and Memphremagog Basins.3/

	Dissolved P					Adsorbed P		
	Barnyards	Manure Stacks	Milkhouse Waste	Manured Fields	Sum Dissolved P	Soil Erosion	Total Phosphorus 1/	Total Available 2/
CHAMPLAIN BASIN								
Phosphorus (lbs)	24,070	2,780	9,200	35,010	71,060	267,240	338,300	124,510
Percent of Total Phosphorus	7.1	0.8	2.7	10.3	21.0	79.0	100	--
Percent of Total Available	19.3	2.2	7.4	28.1	57.1	42.9	--	100
MEMPHREMAGOG BASIN								
Phosphorus (lbs)	3,550	980	340	3,500	8,370	8,340	16,710	10,040
Percent of Total Phosphorus	21.2	5.9	2.1	20.9	50.1	49.9	100	--
Percent of Total Available	35.3	9.7	3.5	34.8	83.3	16.7	--	100

1/ Summation of barnyard, manure stacks, milkhouse waste, manured fields, and soil derived phosphorus.

2/ Summation of barnyard, manure stacks, milkhouse waste, manured fields and 20% of soil derived phosphorus.

3/ All sources shown are controllable

Table 4.6 (con't) Sources of Annual Phosphorus Loads from Agriculture Showing the Availability of Phosphorus from Study Areas in Harvey's Lake and Shelburne Pond. 3/

Basin	Dissolved P					Adsorbed P		
	Barnyards	Manure Stacks	Milkhouse Waste	Manured Fields	Sum Dissolved P	Soil Erosion	Total Phosphorus 1/	Total Available 2/
HARVEY'S LAKE								
Phosphorus (lbs)	180	20	90	170	460	2,900	3,360	1,040
Percent of Total Phosphorus	5.4	0.6	2.7	5.1	13.8	86.2	100	--
Percent of Total Available	17.3	1.9	8.7	16.3	44.2	55.8	--	100
SHELBURNE POND								
Phosphorus (lbs)	180	0	80	260	520	380	900	600
Percent of Total Phosphorus	20	0	8.9	28.9	57.8	42.2	100	--
Percent of Total Available	30	0	13.3	43.3	86.6	13.4	--	100

1/ Summation of barnyard, manure stacks, milkhouse waste, manured fields, and soil derived phosphorus.

2/ Summation of barnyard, manure stacks, milkhouse waste, manured fields and 20% of soil derived phosphorus.

3/ All sources shown are controllable

Geographical distribution of total and available phosphorus loadings delivered to the various water quality management areas is shown in Table 4.7. Discussions of phosphorus loads to each of the WQMA's are provided in ascending order.

The South Main Lake WQMA, whose subbasin includes a portion of the Lower Lake Champlain Watershed and all of Lewis Creek, Little Otter Creek, New Haven River, Lower Otter-Dead Creeks, Lemon Fair, and Middle Otter Creek Watersheds, provides 204,070 pounds of total phosphorus to Lake Champlain. This loading corresponds to 73,850 pounds of available phosphorus, the largest phosphorus loading to any single WQMA. Approximately half of the available phosphorus is derived from soil erosion and the other half from animal waste.

Trout River, Tyler Branch, Rock River and Pike Creek, and Black Creek comprise the subbasin which feeds the Missisquoi WQMA. Total phosphorus equal to 50,550 pounds, or the equivalent of 21,010 pounds of available phosphorus, is derived from this subbasin annually.

South Lake WQMA contains a portion of the Lower Lake Champlain Watershed and the entire Mettawee River Watershed. This subbasin loads 55,410 pounds of total phosphorus annually, or 17,550 pounds in the available form. Available phosphorus loads are split about equally between animal waste and soil erosion sources.

Malletts Bay and Central Main Lake are the two remaining WQMA's associated with Lake Champlain. Both contribute relatively minor loads in comparison to the other WQMA's described above. Total phosphorus loads are 19,380 pounds annually for central main lake and 8,790 pounds for Malletts Bay. Available phosphorus depositions vary somewhat, with 4,130 and 7,870 pounds loaded to Malletts Bay and Central Main Lake, respectively.

Memphremagog subbasin loads 16,710 pounds of total phosphorus divided evenly between animal waste and soil erosion as sources. Converted to available form, animal waste is responsible for 8,340 pounds or 83 percent of loadings. This underscores the need to control animal waste in this basin.

Harvey's Lake subbasin provides 3,360 pounds of total phosphorus corresponding to 1,040 pounds of available phosphorus. Loads of available phosphorus from animal waste and soil erosion are approximately equal.

Total phosphorus loads from the Shelburne Pond subbasin equal 900 pounds, or 600 pounds of available phosphorus. The majority of the available load comes from animal waste.

Knowledge of the seasonal loading distribution of phosphorus and times of critical biological sensitivity to phosphorus loading in the receiving water body allows refinement of best management practices to curtail phosphorus loadings. Often the timing of phosphorus loads may

Table 4.7 Geographical Distribution of Controllable Nonpoint Source Agricultural Phosphorus Loadings from Study Areas to Lake Champlain Water Quality Management Areas (WQMA's)

WQMA	Dissolved P					Adsorbed P		
	Barnyards	Manure Stacks	Milkhouse Waste	Manured Fields	Sum Dissolved P	Soil Erosion	Total Phosphorus 1/	Total Available 2/
	Lbs							
MISSISQUOI								
Phosphorus (lbs)	2,970	540	1,120	9,000	13,630	36,920	50,550	21,010
Percent of Total Phosphorus	5.9	1.1	2.2	17.8	27.0	73.0	100	--
Percent of Total Available Phosphorus	14.1	2.6	5.3	42.8	64.8	35.2	--	100
MALLETTS BAY								
Phosphorus (lbs)	1,140	160	170	1,590	3,060	5,830	8,890	4,230
Percent of Total Phosphorus	13.0	1.8	1.9	18.1	34.8	65.2	100	-
Percent of Total Available Phosphorus	27.6	3.9	4.1	38.5	74.1	25.9	--	100

1/ Summation of barnyard, manure stacks, milkhouse waste, manured fields and soil derived phosphorus.

2/ Summation of barnyard, manure stacks, milkhouse waste, manured fields and 20% of soil derived phosphorus.

Table 4.7 (Con't) Geographical Distribution of Controllable Nonpoint Source Agricultural Phosphorus Loadings from Study Areas to Lake Champlain Water Quality Management Areas (WQMA's)

	Dissolved P					Adsorbed P		
WQMA	Barnyards	Manure Stacks	Milkhouse Waste	Manured Fields	Sum Dissolved P	Soil Erosion	Total Phosphorus 1/	Total Available 2/
	Lbs							
CENTRAL MAIN LAKE								
Phosphorus (lbs)	1,290	180	350	3,170	4,990	14,390	19,380	7,870
Percent of Total Phosphorus	6.6	0.9	1.8	16.4	25.7	74.3	100	--
Percent of Total Available Phosphorus	16.4	2.3	4.4	40.3	63.4	36.6	--	100
SOUTH MAIN LAKE								
Phosphorus (lbs)	15,890	1,370	6,740	17,290	41,290	162,780	204,070	73,850
Percent of Total Phosphorus	7.7	<1.0	3.3	8.5	20.2	79.8	100	--
Percent of Total Available Phosphorus	21.5	1.9	9.1	23.4	55.9	44.1	--	100

1/ Summation of barnyard, manure stacks, milkhouse waste, manured fields and soil derived phosphorus.

2/ Summation of barnyard, manure stacks, milkhouse waste, manured fields and 20% of soil derived phosphorus.

Table 4.7 (Con't.) Geographical Distribution of Controllable Nonpoint Source Agricultural Phosphorus Loadings from Study Areas to Lake Champlain Water Quality Management Areas (WQMA's)

WQMA	Dissolved P					Adsorbed P		
	Barnyards	Manure Stacks	Milkhouse Waste	Manured Fields	Sum Dissolved P	Soil Erosion	Total Phosphorus 1/	Total Available 2/
	Lbs							
SOUTH LAKE								
Phosphorus (lbs)	2,780	530	820	3,960	8,090	47,320	55,410	17,550
Percent of Total Phosphorus	5.0	1.0	1.5	7.1	14.6	85.4	100	--
Percent of Total Available Phosphorus	15.7	3.0	4.7	22.6	46.1	53.9	--	100
MEMPHREMAGOG								
Phosphours (lbs)	3,550	980	340	3,500	8,370	8,340	16,710	10,040
Percent of Total Phosphorus	21.2	5.9	2.0	20.9	50.0	50.0	100	--
Percent of Total Available Phosphorus	35.4	9.8	3.4	34.9	83.5	16.5	--	100

1/ Summation of barnyard, manure stacks, milkhouse waste, manured fields and soil derived phosphorus.

2/ Summation of barnyard, manure stacks, milkhouse waste, manured fields and 20% of soil derived phosphorus.

Table 4.7 (Con't.) Geographical Distribution of Controllable Nonpoint Source Agricultural Phosphorus Loadings from Study Areas to Lake Memphremagog, Harvey's Lake, and Shelburne Pond Water Quality Management Areas (WQMA's)

	Dissolved P					Adsorbed P		
WQMA	Barnyards	Manure Stacks	Milkhouse Waste	Manured Fields	Sum Dissolved P	Soil Erosion	Total Phosphorus 1/	Total Available 2/
	Lbs							
HARVEY'S LAKE								
Phosphorus (lbs)	180	20	90	170	460	2,900	3,360	1,040
Percent of Total Phosphorus	5.4	<1	2.7	5.1	13.7	86.3	100	--
Percent of Total Available Phosphorus	17.3	<1	8.7	16.3	42.3	57.7	--	100
SHELBURNE POND								
Phosphorus (lbs)	180	0	80	260	520	380	900	600
Percent of Total Phosphorus	20.0	0	8.9	28.9	57.8	42.2	100	--
Percent of Total Available Phosphorus	30.0	0	13.3	43.3	86.6	13.4	--	100

1/ Summation of barnyard, manure stacks, milkhouse waste, manured fields and soil derived phosphorus.

2/ Summation of barnyard, manure stacks, milkhouse waste, manured fields and 20% of soil derived phosphorus.

have a greater bearing on the probability of algae blooms than the magnitude of loadings. Seasonal loadings of dissolved phosphorus from barnyards, manure stacks, milkhouses and field spread manure are shown in Table 4.8. Phosphorus entering runoff from barnyards and milkhouses is assumed to occur proportionately throughout the year and is reduced through delivery ratio adjustments (SCS, 1982). Phosphorus loads from manure stacks enter runoff during seasons in which manure is not spread and only for farms without storage facilities. Losses of dissolved phosphorus from manured fields are calculated using seasonal runoff coefficients and delivery ratios. Seasonal dissolved phosphorus loadings to the eight WQMA's all show the main flush of phosphorus comes from manure which runs off in snowmelt.

Dissolved phosphorus loads from soil erosion are not included in Table 4.8. The reason is that the Universal Soil Loss Equation, used in estimating phosphorus losses from soil, is an erosion model designed to predict long-term average soil movement. Attempts to use this equation to predict seasonal soil losses, and hence phosphorus losses, would be inappropriate. In addition, lack of knowledge concerning the physiochemical interactions of phosphorus in stream transport and associated lag time between phosphorus entrance and exit from stream flow underscores the tenuousness of predicting seasonal adsorbed phosphorus loads.

The most rigorous approach to estimating phosphorus mass loadings involves measuring stream concentrations and flows. Total and orthophosphorus loads were estimated using this approach in the LaPlatte River Watershed (Cassell and Meals, 1981). Data from a small but intensively farmed subwatershed indicate phosphorus loads were low except during high flows associated with spring runoff and storm events. In general, similar seasonal patterns of phosphorus loading are likely to occur in the Vermont Runoff Study Watersheds.

In conclusion, large portions of agricultural loads from the Champlain and Memphremagog basins, Harvey's Lake and Shelburne Pond watersheds can be controlled through implementation of best management practices. Pastures are the only agricultural phosphorus source for which there are no practicable controls. Pasture phosphorus loads were shown to be relatively insignificant in comparison to other agricultural sources. Dissolved phosphorus provided the largest proportion of available phosphorus loads to the Champlain and Memphremagog basins and Shelburne Pond. In the Harvey's Lake watershed, the adsorbed percentage of total available phosphorus exceeds the dissolved portion. South Main Lake and Malletts Bay WQMA's receive the largest and smallest available phosphorus loads, respectively, in Lake Champlain. Seasonal loadings of dissolved phosphorus indicate the major "pulse" occurs as the result of winter snow melt.

Table 4.8 Seasonal Distribution of Controllable Nonpoint Source Agricultural Dissolved Phosphorus Loadings to the Lake Champlain Water Quality Management Areas.

	Barnyards	Manure Stacks	Milkhouse Waste	Manured Fields	Sum of Dissolved P
			Pounds		
<u>Missisquoi</u>					
Winter	1,320	420	490	5,880	8,110
Spring	550	0	210	1,650	2,410
Summer	550	100	210	510	1,370
Fall	550	20	210	960	1,740
<u>Malletts Bay</u>					
Winter	420	160	50	1,160	1,790
Spring	140	0	40	130	310
Summer	240	0	40	160	440
Fall	240	0	40	140	420
<u>Central Main Lake</u>					
Winter	430	10	110	2,590	3,240
Spring	290	90	80	130	540
Summer	290	0	80	300	650
Fall	280	80	80	150	560
<u>South Main Lake</u>					
Winter	5,540	820	2,370	12,800	21,910
Spring	3,450	270	1,460	1,920	7,000
Summer	3,450	190	1,460	1,210	6,170
Fall	3,450	80	1,460	1,360	6,210
<u>South End Lake</u>					
Winter	1,100	450	300	2,900	4,680
Spring	560	70	170	650	1,460
Summer	560	10	180	250	1,020
Fall	560	0	170	160	920

Table 4.8 (Con't.) Seasonal Distribution of Controllable Nonpoint Source Agricultural Dissolved Phosphorus Loadings to the Lake Memphremagog, Harvey's Lake, and Shelburne Pond Water Quality Management Areas.

	Barnyards	Manure Stacks	Milkhouse Waste	Manured Fields	Sum of Dissolved P
			Lbs		
<u>Memphremagog</u>					
Winter	1,270	480	130	1,500	3,380
Spring	760	0	70	1,400	2,230
Summer	760	400	70	60	1,290
Fall	760	100	70	540	1,470
<u>Harvey's Lake</u>					
Winter	60	20	30	40	150
Spring	40	0	20	30	90
Summer	40	0	20	30	90
Fall	40	0	20	70	130
<u>Shelburne Pond</u>					
Winter	60	0	20	200	280
Spring	40	0	20	30	90
Summer	40	0	20	10	70
Fall	40	0	20	20	80

Forestry

Undisturbed forest land is an uncontrollable nonpoint source of phosphorus and represents over 90 percent of the total phosphorus yield from forest land.

Controllable forest land sources are those which are undermanaged during harvesting. They are the critically eroding areas laid bare by skidding and hauling of timber and firewood through and out of the forest. They represent only about .01 percent of the total forest area in any given year.

Table 4.9 provides a summary of the average annual phosphorus loads from these forest land sources. It is clear from the table that emphasis should be given to controlling phosphorus from forest harvesting in watersheds emptying to South Main Lake Champlain and Lake Memphremagog. Table 4.9 is expressed in terms of total phosphorus loads. Only about 20 percent of this value is estimated to be available for aquatic plant growth.

Table 4.9. Estimates of Nonpoint Source Forest Land Phosphorus Loadings by WQMA

	Average Annual Total Phosphorus Yield		
WQMA	Undisturbed Forest	Forest Haul Roads	Total Forest
		Pounds per year	
Lake Champlain			
Missisquoi Bay	4,270	415	4,685
Malletts Bay	1,830	55	1,885
Central Main Lake	2,860	175	3,035
South Main Lake	8,960	815	9,775
South Lake	2,020	45	2,065
Subtotal	19,940	1,505	21,445
Lake Memphremagog	4,360	750	5,110
Shelburne Pond	40	0	40
Harvey's Lake	295	10	305
Total	24,635	2,265	26,900

CHAPTER 5

FINDING SOLUTIONS TO RUNOFF PROBLEMS

An understanding of the mechanisms operating in agricultural and silvicultural nonpoint runoff, discussed in the last chapter, leads to practices which can control these sources. Control practices are analyzed in this chapter and their physical and economic effects discussed. Planning for runoff control then becomes a process of combining control practices in ways appropriate to achieve recognized goals. Different plans are possible within this process corresponding to different combinations of practices. The effectiveness of the alternative plans can be seen by comparing results expected from implementing each plan.

ANALYSES

Analyses in this section are based on sampled data drawn from farms in the study watersheds. The process of evaluating the raw data and estimating phosphorus loads involved the use of a fortran computer program called PHSRED and three separate programs written for use with the Statistical Analysis System (SAS) software package. The PHSRED program is designed to evaluate adsorbed phosphorus losses from soil erosion and dissolved phosphorus losses from manured fields. The SAS programs are used to estimate dissolved phosphorus loads from barnyards, manure stacks and milkhouses. The following discussion relates the fundamental components of each methodology. The reader is referred to SCS (1982) for a more complete explanation of the methods used.

Animal Waste Management

Field Spread Manure

The primary objective for a manure management system is to store manure during high runoff periods so that manure can be spread and incorporated into the soil, minimizing nutrient loss. Three storage periods (90, 180 and 360 days) were considered, and analysis of loss rates indicates that 180 days of storage is needed so that incorporation in spring and fall can be accomplished (Heimlich, 1982).

All plan alternatives assumed 180 days of storage with incorporation of manure in spring and fall. For purposes of the economic analysis discussed below, preferred systems were chosen for stanchion and free stall housing based on the experience of SCS engineers with the various systems available. Farms with stanchion barns are assumed to require gutter cleaners to move manure to a piston pump which then transfers it to an earthen storage with ramp and picket dam (see Figure 5.1). Manure is handled as a semi-solid. Farms with free stall housing are assumed to require a tractor scraper to move manure to a piston pump which transfers it to an earthen pit storage (see Figure 5.2). Manure is handled as a liquid. See Technical Report No. 2 (Heimlich, 1982) for a detailed analysis of system costs.

Fig. 5.1 Stanchion Dairy Barn with Gutter Cleaner, Piston Pump and Earthen Storage.

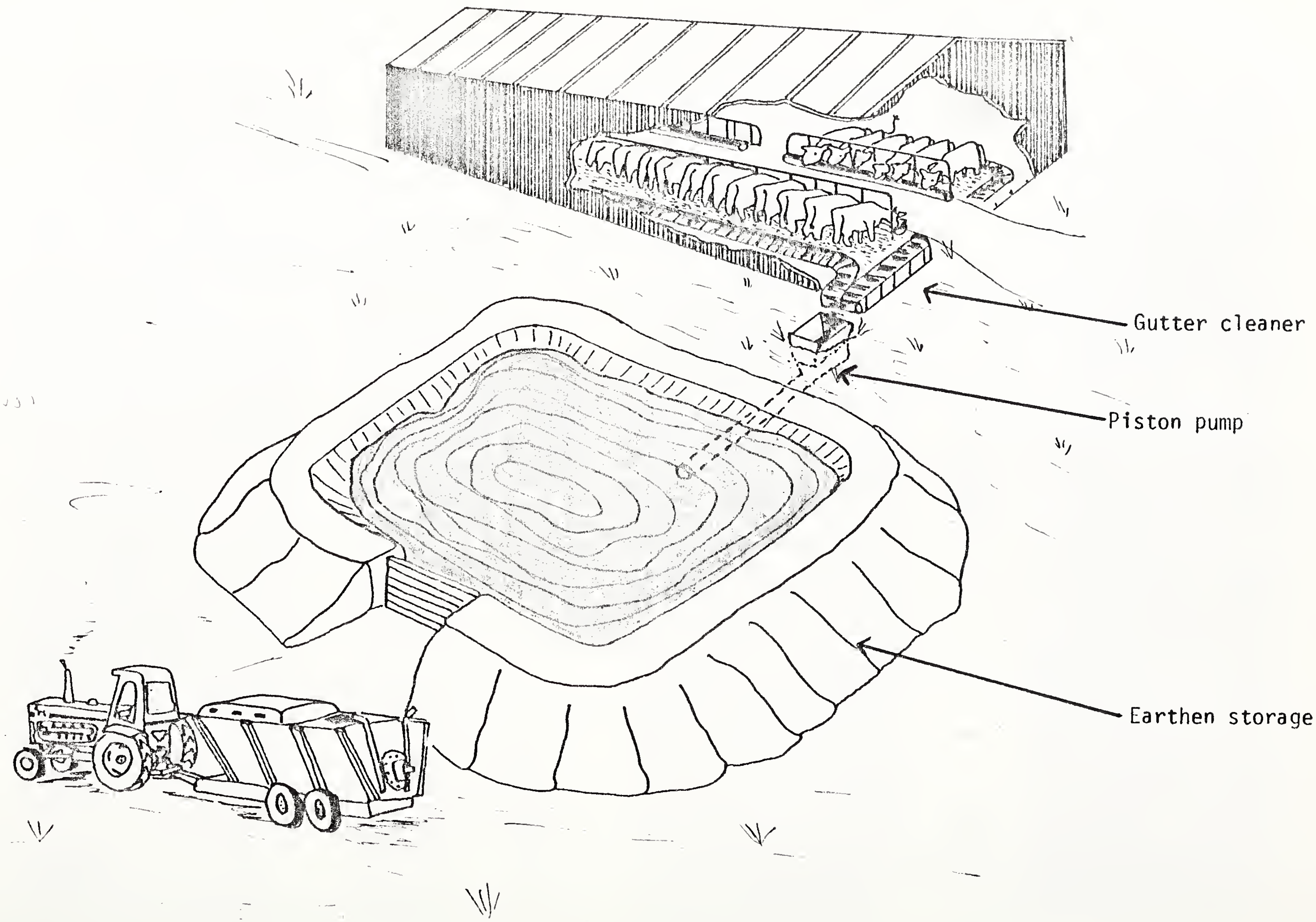
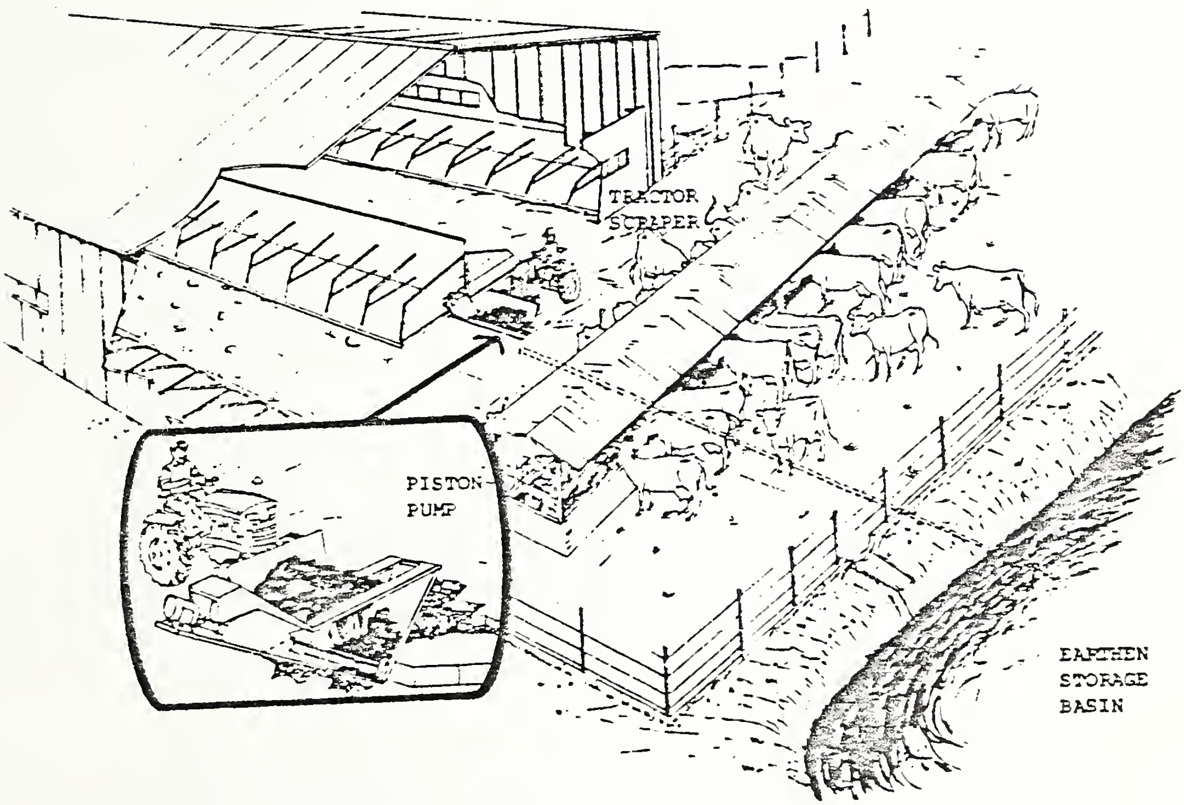


Fig. 5.2 Free Stall Dairy Barn with Tractor Scraper, Piston Pump and Earthen Storage Basin Waste System.



Adapted from White and Forster, 1978.

All farms were required to have 180 days of adequate manure storage in the plan alternatives. Farms that had manure storage under existing conditions or were stacking manure in an area more than 400 feet from the nearest stream were considered to have adequate systems. All others were assumed to install one of the preferred systems, depending on housing type.

Barnyards

Estimates of phosphorus losses from barnyard sources are based upon a methodology developed by Draper, Robinson, and Coote (1978). They estimate that the phosphorus content in 5 percent of the total farm manure production enters runoff from barnyards. This initial load is attenuated linearly in overland flow. If the nearest water course is over 400 feet from the edge of the barnyard, only background levels of phosphorus are assumed to enter stream flow during runoff events occurring in spring, summer and fall. Runoff events from winter snow accumulations are assumed to be unattenuated. This occurs because soil surfaces are generally frozen during periods of snowmelt preventing infiltration. Vegetative absorption of phosphorus during snowmelt is negligible.

Best management techniques to reduce the hazards of barnyard-derived phosphorus consist of implementing a combination of practices. Included are roof gutters, diversion of clean water around barnyards and the installation of concrete pads under barn cleaners and outside barn doors (Esser, 1982). In addition, grading and shaping may be necessary to direct runoff to filter strips located between the barnyard and water course.

Manure Stacks

Phosphorus losses from stacked manure occur generally from piles in the barnyard or in remote field stacks. Installation of a manure storage facility coupled with a seasonal spreading distribution designed to minimize phosphorus losses eliminates the problem of haphazard piling. The storage structure prevents seepage and subsequent phosphorus losses during peak runoff times. From a water quality standpoint, manure stacks located more than 400 vegetated feet from a watercourse do not pose a problem. Phosphorus losses from stacks are calculated for farms which indicated in the sample inventory that manure was stacked at some time during the year. In addition, the stack must be within 400 feet of a watercourse in order to contribute a phosphorus load.

Milkhouse Waste

Milkhouse waste may contribute phosphorus to watercourses when improperly managed. As in the barnyard and manure stack

methodologies, calculations of phosphorus loads from milkhouses are made only when the distance to the nearest watercourse is less than 400 feet.

Techniques to manage milkhouse waste are related to the type of manure management system installed. Liquid manure systems utilize milkhouse waste water, insuring that an adequate slurry is maintained. Management systems associated with conventional housing use a semi-solid manure system which cannot utilize milkhouse waste water. In the methodology used in this study, freestall barns are assumed to install liquid systems and conventional barn types are assumed to use semi-solid systems. Disposing of milkhouse waste in a liquid manure system essentially eliminates phosphorus loadings from milkhouses. Conventional barn types are assumed to dispose of milkhouse waste with a level lip spreader and buffer strip.

Existing condition phosphorus loadings from milkhouses are reduced linearly with distance until at some critical distance phosphorus levels are reduced to background levels. Under managed conditions, phosphorus attenuation from level lip spreaders and buffer strips is assumed to be 50 percent. A complete analysis of the milkhouse phosphorus load methodology is given in Technical Report No. 1 (SCS, 1982).

Cropland Erosion Control

Adsorbed phosphorus loadings from cropland result directly from loss of soil by erosive processes. Through erosion and sedimentation, phosphorus laden soil particles are deposited in streams and transported to receiving water bodies.

Quantification of soil loss is accomplished using the Universal Soil Loss Equation (USLE). The equation is as follows:

$$A = RKLSCP$$

where:

- A = soil loss in tons per acre per year (T/A/Y);
- R = rainfall and runoff factor;
- K = soil erodibility factor;
- (LS) = slope and steepness factor;
- C = cover and management factor; and
- P = support practice (contour plowing, etc.).

Basically, soil loss reductions are estimated by manipulating the LS, C, and P factors using the following practices either singly or in combination: conservation tillage; conservation cropping systems; contour plowing; contour stripcropping; conversion to permanent hay; or diversions (SCS, 1982). Arranging soil conservation practices in various sequences provides options for dealing with erosion. As can be seen from the number of practices, many combinations are

possible. For instance, achievement of a target soil loss rate may be accomplished by changing the cropping factor, or perhaps changing only the current practice factor, or modifying both. Pragmatism, however, requires that criteria be established to limit choices. The criteria used in the PHSRED program is the normal procedure used in drawing up a farm conservation plan and is used to order the sequence of conservation practices.

In choosing to restrict options in this manner, changes in cropping patterns are first implemented. Practice factor changes, such as shifting from plowing up and down slope to contour or contour stripcropping, follow. Other options may include installation of diversions and conversion to permanent hay if necessary to achieve soil loss reduction goals.

Estimating soil loss with the Universal Soil Loss Equation in the PHSRED program requires specification of a level of control as a goal. Three levels, including the "soil tolerance level" or "T Value", 5- and 10-ton per acre per year levels are used as goals in the computer program. The output from the program then provides the numerical basis for various alternative plans.

Limitations, due either to agronomic factors or inherent constraints in the computational algorithms, restrict the use of certain conservation practices. Conservation tillage, for instance, has not proven successful under current management levels on clayey soils such as the Vergennes and Covington series found in Addison County. Lack of adequate drainage tends to keep the soils wet and cold in springtime, a condition exacerbated with conservation tillage. In addition, the requisite 1500 to 2000 pounds of surface residue requires aerial seeding of a fall cover crop. Success has been limited in establishing fall cover crops on the Vergennes and Covington soils.

Another limitation deals with the criteria used to order the sequence of conservation practices in the PHSRED program. As mentioned above, the criteria used to establish the sequence order is the normal procedure used by soil conservationists in drawing up a farm plan. This procedure uses a C factor change first which reduces the level of corn production. An alternative would be to implement a new P factor instead of initially limiting the frequency of corn in rotation through a C factor change. For example, soil erosion might be reduced to "T value" through changing tillage from up and down slope to on the contour. Contour tillage with stripcropping might also be employed. The criteria discussed so far show that the ordering of practice sequences follows a conservation planning logic. Another approach would be to assign costs to the various practices and choose practices on a least cost basis. This would reorient current conservation planning criteria to be responsive to economic factors.

A complete discussion of the methods used to derive best management practices and their evaluation in terms of sediment and phosphorus yields is given in Technical Report No. 1 (SCS, 1982).

Economics

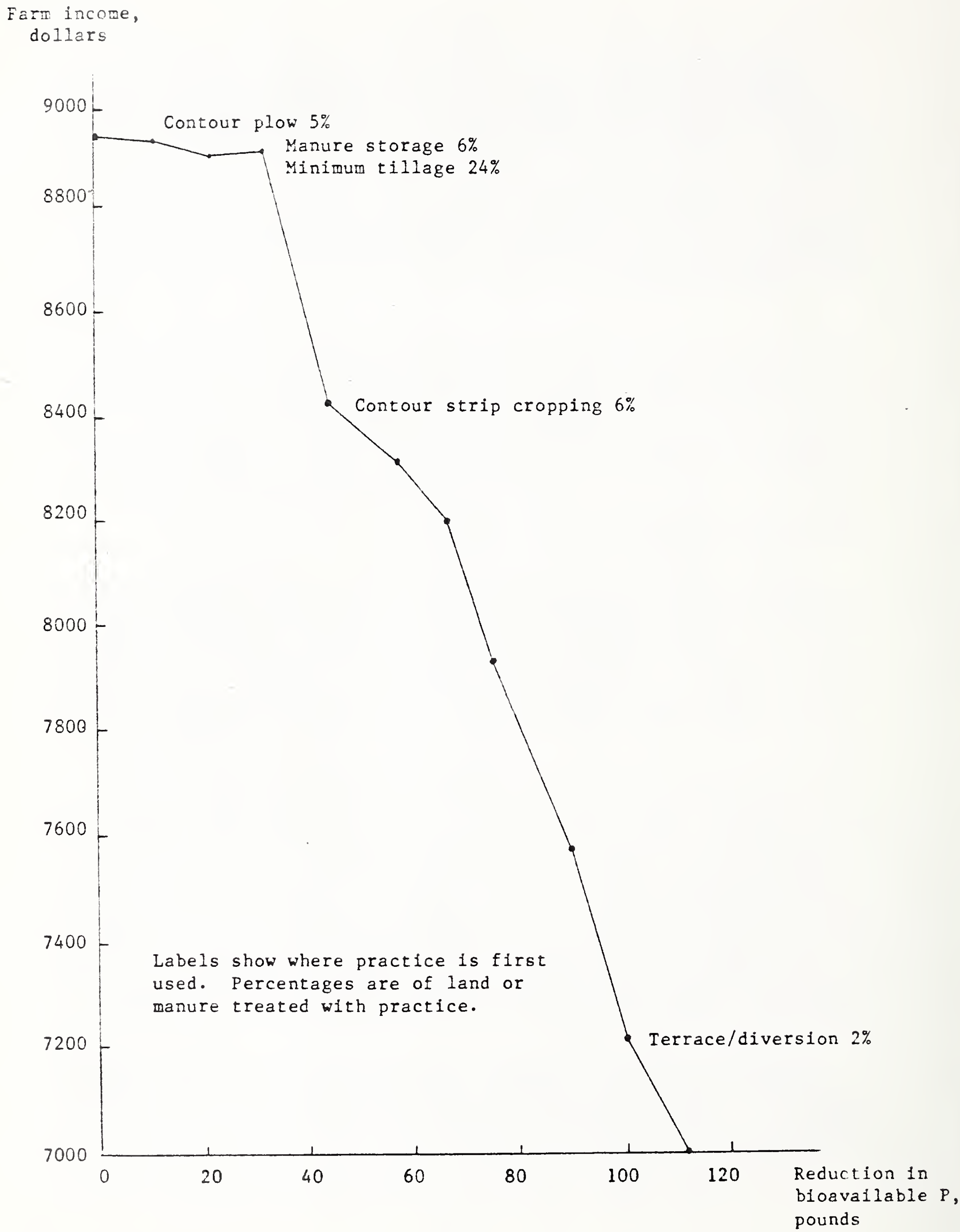
Tradeoffs between phosphorus reduction and farm income were examined using mathematical models of typical dairy farms at three herd sizes: 35 cows, 54 cows and 116 cows. The model simulates all of the economic components of the dairy farm, including herd management, feeding and milk production, crop production and storage, manure handling, and finances and taxes. Phosphorus and soil losses are associated with each crop activity. Thus, the economic and environmental aspects of the farm operation are simultaneously modeled. A complete description of the model and analysis is contained in Technical Report No. 2 (Heimlich 1982).

The relationship between farm income and phosphorus loss was analyzed by first maximizing net farm income and observing the level of phosphorus loss. Then runs were made requiring successive reductions in allowable phosphorus loss while maintaining as high a level of net farm income as possible. No Government subsidies or cost sharing of practices installed is considered here. In this fashion, the most efficient way to reduce phosphorus loss is traced out. Such a tradeoff curve for the small farm is shown in Figure 5.3. The pattern of adjustments to successively lower phosphorus loss can be discussed generally in terms of this curve.

Initial reductions in phosphorus loss from the base level are obtained at no cost by shifting the manure spreading schedule between crops and seasons spread. For example, manure can be spread on corn in spring or fall and incorporated, thus reducing dissolved P losses. Reductions up to 10 percent can be made in this range. The next level of reductions, up to 20 percent, requires some control of soil erosion to reduce adsorbed P losses. Relatively inexpensive practices like contour plowing and minimum tillage are used, reducing income by four-tenths of one percent of base levels. Between the 20 and 70 percent P reduction levels, an increasing fraction of the farm's manure must be stored so that greater shifts in the spreading schedule can be accomplished. More erosion control is required, with contour stripcropping replacing contour plowing on some acres. Some minimum tillage is used. Income at this level (70 percent) is 11.3 percent lower than in the base solution. Finally, the last increment of phosphorus control, between 70 and 100 percent, requires that all manure be stored up to 180 days so that spreading can occur in spring and fall and manure can be incorporated. Erosion is reduced to 24 percent of the base level, requiring more stripcropping and several acres of terraces. At the 90 percent reduction level, income is 19.3 percent lower than the base.

Phosphorus reduction requires control of both dissolved nutrients from manure handling and adsorbed nutrients attached to eroded soil particles. Reducing erosion alone reduced phosphorus only 40 percent and farm income declined 5.3 percent.

FIGURE 5.3. Tradeoff Between Farm Income and Phosphorus Control, Small Farm



Within this general pattern of response to phosphorus reductions, economies of size operate. The principal difference between the small farm and the medium and large farms is that medium and large operators have an economic incentive to use some manure storage even if no phosphorus reductions are required. For example, the large farm increases farm income 33 percent ($4,689) with 45 percent of its manure stored in an earthen pit (free stall barn) compared with daily spreading in a stanchion barn. Savings in operating costs, labor, fertilizer and income taxes offset the debt service required for manure storage. The costs of converting from stanchion to free stall barn configuration are not included here. This makes initial reductions in phosphorus loss much easier to attain than is the case for small farms.

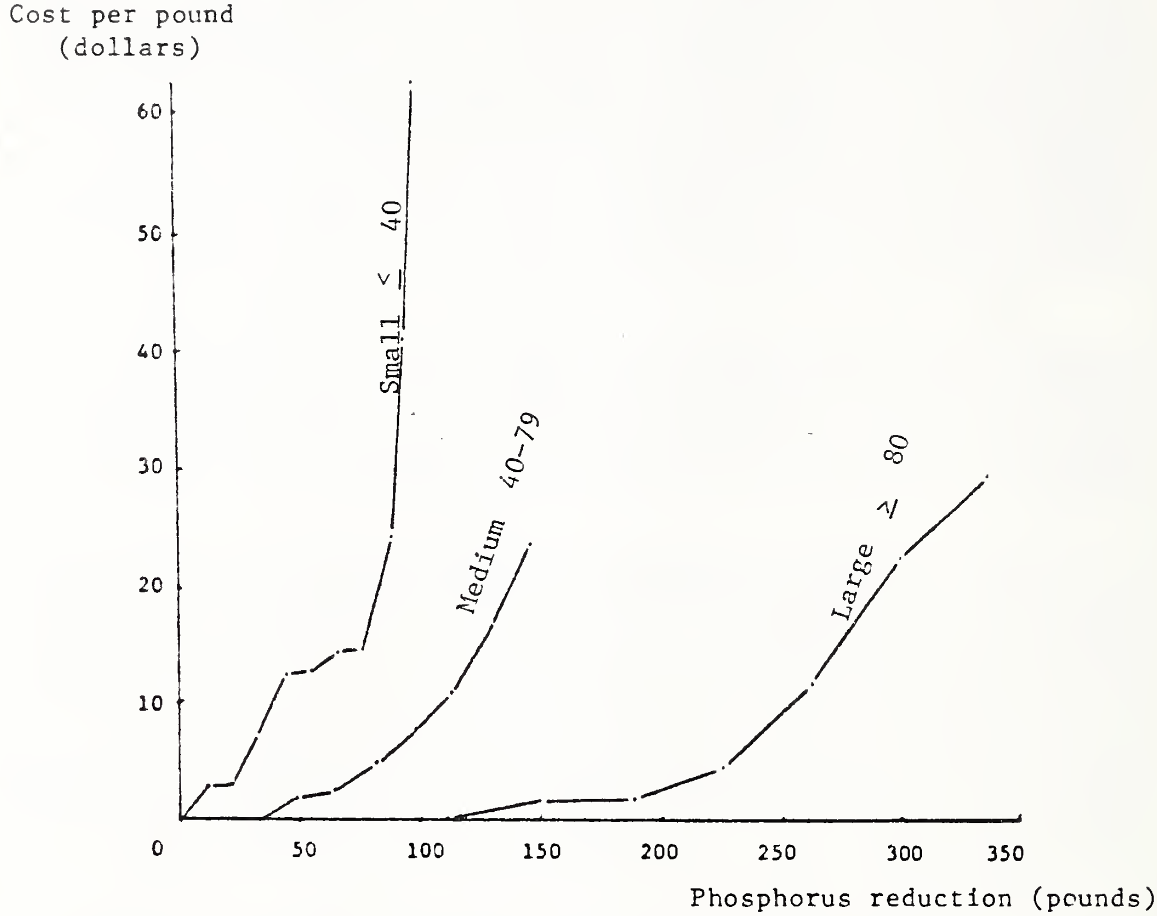
At most levels of phosphorus reduction, larger farms incur larger absolute loss of farm income and smaller losses as a percentage of base income. At the 90 percent reduction level, for example, income losses are $1,726, $1,203, and $1,940 for small, medium and large farms, but these are 19.3, 8.9 and 10.3 percent of respective base incomes.

Marginal costs of phosphorus reduction by farm size are shown in Figure 5.4. This figure illustrates that phosphorus control is more expensive for smaller farms. For example, a reduction of 100 pounds costs $62.96 per pound on the small farm but only $7.65 per pound on the medium farm and $0.10 on the large farm. From a slightly different perspective, a "price" of $6.62 per pound of phosphorus loss reduced yields only 31.8 pounds on the small farm, 81.5 pounds on the medium farm and 227.0 pounds on the large farm. Larger farms generate more phosphorus runoff than smaller ones, so that control of phosphorus on these farms is more cost effective than on smaller farms.

Economics of size are important in any control strategy for phosphorus. A strategy requiring equal percentage reductions in phosphorus loss will have unequal economic impacts on farm income. Uniform requirements for manure storage or erosion control will not affect incomes uniformly. Cost-share policy could take farm size into account, providing a larger cost-share rate for smaller farms to offset the greater economic impact of phosphorus control measures. Small farms might be excluded from control programs altogether, since their contribution to phosphorus loss is small relative to costs of control.

Finally, the response of farm income to phosphorus control measures is not static but is subject to pressures in the market place that can have disproportionate effects. The results discussed above were obtained for prevailing interest rate of 10 percent and milk price of $11.49 (per cwt.) of the 1979 model base year. Since 1979, interest rates have risen dramatically and new milk support prices were legislated in the 1981 Farm Bill. The affect of these exogenous economic forces on phosphorus control programs was analyzed for the medium farm.

Figure 5.4. Marginal Cost of Phosphorus Reduction by Farm Size



When interest rates go up to 15 percent, the same 90 percent reduction in phosphorus now costs $1,534 instead of $1,203 on the medium farm. As a percentage of base income, the loss in income more than doubles to 17.8 percent instead of 8.9 percent. Thus, a 50 percent rise in interest rates changes the absolute loss in income less than proportionally, but this loss is a greater percent of base income since higher interest rates decrease base income.

Changes in dairy support prices contained in the 1981 Farm Bill (PL97-98, 95 Stat. 1328, Title I) mean that milk prices will increase only 11.4 percent over the 1981-1985 period. If the costs of dairy inputs in Vermont continue to rise at the 10.2 percent average annual level of the last five years, real revenue from dairy production will drop almost 30 percent over the next four years. Even if the costs of phosphorus control measures stay constant, the impact of a phosphorus control program will be greater because the farm income base will be lower. Declining real milk price was analyzed for the small farm. A 10 percent drop in real milk price ($11.49 to $10.34 per cwt.) resulted in a 53 percent drop in farm income. A further 3.5 percent drop

in milk price resulted in an infeasible solution. Thus, a 13.5 percent reduction in real milk revenues may be enough to force many smaller dairy operations out of business.

Forest Management

Management of soil loss and attendant phosphorus loss from logging operations consists of adopting practices which will minimize the amount of disturbed area, reduce runoff from disturbed areas, retard and divert storm runoff, filter sediment before reaching a watercourse and provide a stable base for logging equipment.

Logging methods prescribed are summarized as follows:

1. Prior to the logging operation, develop a road system plan for minimizing roads and skid trails;

2. Construct the roads and trails to meet the following standards:

   -- Gradients below 10 percent (steep pitch permitted if short;

   -- Locate parallel to, and away from, streams;

   -- Provide good drainage or refrain from logging operations when equipment rutting occurs;

3. Protect the road from erosion when logging operations cease (vegetation, water control, vehicle exclusion, etc.).

Critically eroding areas may exist in undisturbed forest and should be included in a phosphorus management plan if cost is not prohibitive. There were very few such areas observed during the study. Causes could be livestock overgrazing, streambank erosion or burned-over areas where vegetation has not been reestablished.

Forest logging activities produce higher phosphorus loads in watersheds along the base of the Green Mountains and in the Vermont Piedmont. Management activities should concentrate in these watersheds for "worst-first" and most effective treatment for water quality protection.

On the other hand, watersheds 4, 5, 7, 10, 12, 14 and 16 in the Champlain Lowlands should be closely scrutinized during development of water quality protection plans. Little, if any, forest trail and road treatment may be warranted for cost efficient reduction of phosphorus there.

DEVELOPING THE ALTERNATIVES

Plan Formulation

The Suggested Plan discussed in Chapter 6 has evolved through evaluation of several alternatives for achieving phosphorus control in the individual watersheds and at the basin level. Economic efficiencies, effectiveness in controlling phosphorus and sediment, protection of the soil resource, proper utilization of nutrients and acceptability to potential project participants were all considered in formulating the various alternative plans.

Relationship to Other Plans and Studies

Several regional and state positions or recommendations have been made which have facilitated or guided this study. The State Water Quality Plan for Controlling Agricultural Pollution identifies major sources of agricultural nonpoint source pollution, promotes the voluntary participation approach to agricultural pollution management and prioritizes eight major hydrologic units for project assistance.

The Lake Champlain Level B Study, completed in 1979, deals with critical Lake Champlain basin issues and emphasizes the need for cooperative resource management programs in the state. The study identifies lake water quality preservation and restoration as a major issue. It shows that control of runoff from agricultural land is essential as a part of the solution. It recommends best management practices for agriculture and forestry in priority watersheds.

As a result of these recommendations, three agricultural NPS control projects have been authorized and are now in progress in the St. Albans Bay Watershed (RCWP), LaPlatte River Watershed and Lower Otter and Dead Creeks Watershed (PL-566). These projects have been well received and demonstrate that an acceptable level of participation can be attained using the project approach. In keeping with those recommendations, alternative plans developed during the formulation process feature best management practices which will significantly reduce phosphorus yields, be acceptable in a voluntary program and provide for economic efficiencies.

Common Problems and Solutions

Throughout the study watersheds, common problems are excessive phosphorus and sediment loads to the water quality management areas. Solutions to these problems must consider the impact of corrective measures on the farm business.

In formulating plans to reduce agricultural nonpoint source available phosphorus and sediment reaching the lakes, various mixes of

erosion control and manure management practices must be considered. This is due to the fact that the pollution problem and the source of that pollution varies from watershed to watershed.

Climatic conditions in the Lake Memphremagog basin and in northern Franklin County are not conducive to the cultivation of corn. Consequently, study watersheds 1 through 6, which are located in this region, have a high amount (86 percent) of cropland devoted to hay and a relatively low amount (14 percent) of cropland planted to corn. Here, the agricultural waste sources are more significant for corrective treatment.

On the other hand, watersheds 7 through 17 are located in the Champlain Valley where the climate is more favorable for the cultivation of corn. Over a third (34 percent) of the cropland in these watersheds is devoted to corn with a corresponding decrease in the amount of cropland in hay. Erosion control and agricultural waste management are of nearly equal concern here.

Table 5.1 displays an interesting relationship between the apportionment of cropland, erosion, sediment yield and the contribution of phosphorus from cropland. The northern watersheds, with their relatively smaller percentage of corn land, contribute 60 percent of the available phosphorus from cropland in the form of dissolved phosphorus and 40 percent as adsorbed phosphorus. In contrast, the Champlain Valley watersheds have a much greater percentage of cropland in corn and adsorbed phosphorus becomes the dominant source of available phosphorus (63 percent). This is a result of the increased erosion that can be expected to occur on the corn land.

The strategies employed to reduce the amount of phosphorus delivered from agricultural lands should vary according to the dominant source of this phosphorus. In watersheds such as those in northern Vermont, more manure management practices should be emphasized, with erosion control practices employed to supplement as needed.

In the Champlain Valley, where adsorbed phosphorus is the dominant source of available phosphorus, erosion control practices should be emphasized, with manure management practices added supplementally.

There are some watersheds, such as Malletts Bay, where there is no apparent erosion problem. These watersheds might be approached entirely from a manure management standpoint.

Criteria and Methods Used for Formulation

Nine alternative combinations of conservation practice application were originally considered. All nine of the alternatives differed chiefly in the order in which standard conservation practices were or were not applied. Briefly, the alternatives considered were:

Table 5.1. A Comparison of Agricultural Nonpoint Source Loadings by Climatic Regions

Study Elements	Lake Memphremagog and Northern Vermont (Watersheds 1-6)	Lake Champlain Valley (Watersheds 7-17)
Erosion		
Tons in sample	20,289	158,016
Tons/acre of cropland	1.56	5.20
Sediment delivered		
Tons	2,830	20,712
Tons/acre of cropland	0.22	0.78
Phosphorus delivered		
Dissolved (lbs)	2,797	6,459
Particulate (lbs)	9,454	54,648
Available (lbs)	4,687	17,388
Available phosphorus contribution[1]		
Dissolved (%)	60	37
Particulate (%)	40	63
Dissolved (lb/acre cropland)	0.22	0.24
Particulate (lbs/acre cropland)	0.14	0.42
Total (lb/acre cropland)	0.36	0.66
Cropland apportionment		
Corn (acres)	1,806	8,897
(%)	14	34
Hay (acres)	11,215	17,584
(%)	86	66

[1]Phosphorus available to plant use = 100 percent of dissolved + 20 percent of particulate.

1. Current condition -- Considers only those conservation practices that were in effect at the time of the inventory. No new conservation practices are considered.

2. Conventional tillage only -- Applies the following conservation practices in succession until any specified level of acceptable erosion is achieved. The practices are applied in the order listed.

a. Change the crop rotation reducing the percentage of row crop. (A minimum of two years corn is maintained as a base.)
b. Plow across the field slope.
c. Plow on the contour.
d. Strip-crop on the contour.
e. Install terraces and/or diversions.
f. Convert the field into continuous hay crop.

3. Conservation tillage first practice considered -- Applies the practices in the same order as in alternative 2 above. However, conservation tillage is applied prior to changing crop rotation in all fields containing soils which are compatible with this practice.

4. Conservation tillage considered after rotation change -- A change in crop rotation is considered first and then conservation tillage. Practices b-f, listed in alternative 2 above, are then applied in the same order as listed.

5. Conservation tillage considered before permanent conversion -- Applies the practices as in 2 above but tries conservation tillage as a practice after terraces and diversions and before converting to permanent hay.

Alternatives 6 through 9 are the same as alternatives 2 through 5, respectively, with the exception that fields having erosion rates below T value are allowed to increase the percent of corn in rotation to a point where the erosion equals or is slightly below T value. These four alternatives were explored with an eye toward supplying an alternate source of corn to ameliorate the loss of corn through crop rotation changes in highly eroding fields. The percentage of corn is never increased to a point which would cause erosion at a rate that would allow the soil resource base to deteriorate (greater than T value).

In addition to considering the nine alternatives listed above, four levels of erosion reduction were considered. However, in considering 9 alternatives at 4 different erosion rates for 19 watersheds, 684 different combinations are possible. This created an unwieldy number of combinations despite the aid of a computer model (PHSMED, see Technical Report No. 1) which was developed to analyze the inventory data.

Several watersheds were selected as representative of the two major lake basins. These watersheds were then analyzed using all nine alternatives and with erosion reduction levels which brought all fields below ten tons per acre, seven tons per acre, five tons per acre and to T value, respectively. This supplied the base data to determine the relative effects of the alternatives and erosion reduction rates on sediment and available phosphorus delivered to the water bodies. The sediment and phosphorus reductions were analyzed on the

basis of total reduction and on the basis of cost per unit of reduction. The results were tabulated by watershed, alternative and erosion level.

A series of workshops involving the Vermont Department of Water Resources, ERS and SCS were then held to determine if there was duplication of results among the alternatives. This allowed for a reduction in the number of alternatives and levels of allowable erosion to be investigated in the remaining watersheds of the study.

As a result of these workshops, alternatives 2, 3, 4, 6 and 8 were dropped from consideration, as was an allowable erosion rate of 7 tons per acre. Alternatives 3, 4 and 8 were dropped because the phosphorus and sediment reduction achieved was matched by alternative 7 at a reduced cost. An allowable erosion rate of 7 tons per acre was dropped from consideration because a linear relationship was observed between the 5, 7 and 10 ton per acre rates. Thus, the results for a 7 ton per acre erosion level could be interpolated between the 5 and 10 ton per acre results.

An additional alternative was added as a result of these workshops. The reduction of phosphorus which could be achieved through application of manure management systems only was deemed of interest. Therefore, an alternative was created which employed no erosion reduction practices but did install manure management systems on those farms with no current system.

Having eliminated five alternatives from consideration and having added the manure management only alternative, all nineteen watersheds were processed through the PHSRED model and the results tabulated, on a watershed basis, in terms of erosion reduction, phosphorus reduction, total cost and cost per unit of reduction.

Economic Considerations

Economic aspects of the alternative plans were evaluated from two perspectives: the impact on farmer's income and the costs of implementing these practices under existing program authorities. These often have different economic impacts because the costs are borne at different times and are calculated differently. For example, the cost of a manure storage system to a farmer is the annualized cost of all system components (collection, movement to storage, storage, spreading) less the value of labor and nutrients saved and net of any effects on income taxes. However, the government's cost to subsidize such a manure storage is a one-time payment calculated on the construction cost of the storage component alone.

The economic impact of the plans on farmer's income is equal to the change in net income with the practices required by the plan. This was estimated using shadow prices of practices developed from linear programming models of existing conditions in the study area.

Shadow prices were developed for small (35 cows), medium (54 cows) and large (116 cows) farms in each of five homogeneous clusters of watersheds comprising the study area. Estimates were made for conservation practices, changes in the value of crop rotations, manure systems, barnyard runoff systems and milkhouse waste systems. Details are contained in Technical Report No. 2 (Heimlich 1982).

Total installation costs are for those practices that are eligible for assistance under existing USDA program authorities. District offices were surveyed to determine cost bases for practices currently in use. These were applied to acreages and numbers of practices prescribed in the plan alternatives. Further details of the estimates are contained in Heimlich (1982).

Plan Evaluation

Seven different plans were formulated for each of the watersheds. Each plan had a management goal or a desired effect as a central theme. For example, the plan could be designed to control animal waste or minimize phosphorus delivery. The alternative combinations of conservation practices discussed above were analyzed for each watershed to determine which alternative best fit each plan.

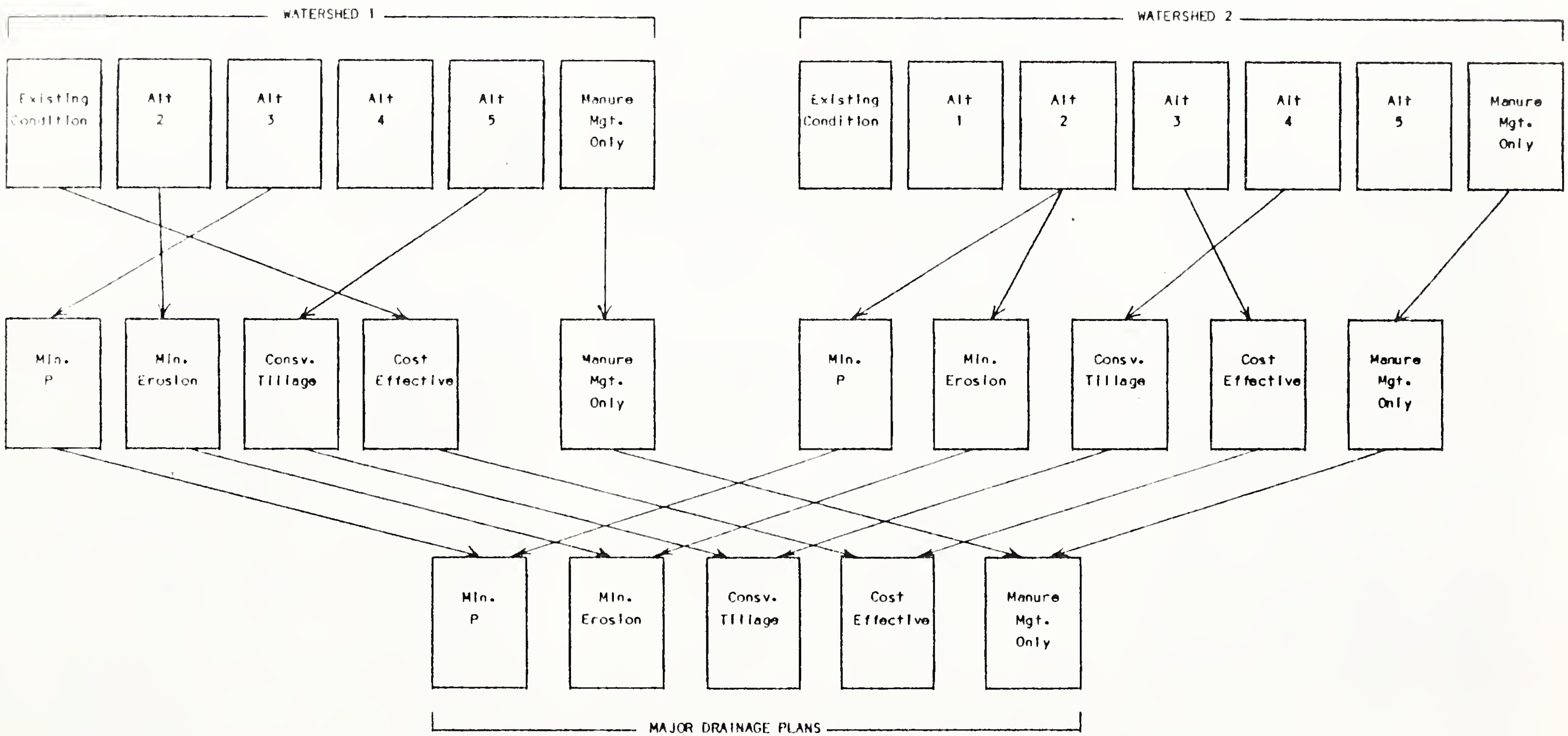
Frequently the same alternative best matched more than one of the plans. When this happened, the same alternative was included in more than one plan. In the Clyde River Watershed, for example, the same alternative combination of practices resulted in the greatest reduction in phosphorus delivered, added the most conservation tillage and was most cost effective. Therefore, that alternative was selected for plans 3, 5 and 6 described below. It was also selected as the suggested plan for that watershed (plan 7). More detailed information on the Clyde River and other watersheds studied is contained in Technical Report No. 5.

Plans for the Lake Champlain and Lake Memphremagog drainages are composites of the individual watershed plans. Each plan may use different alternative combinations of practices in the watersheds making up the major drainages, but they will all best fit the central theme of the plan. The plan formulation process is shown schematically in Figure 5.5. The plans developed are described below.

Future Without Plan

This plan documents the phosphorus and sediment loadings from agricultural lands that can be expected to occur under ongoing programs. It is the future base condition against which the other six plans can be compared.

FIGURE 5.5. Formulation of Plans



To arrive at this plan, the PHSRED program was run for the current condition with regard to erosion, phosphorus delivery and an inventory of conservation practices presently in place. With the current problems and needs determined, the rate at which conservation practices have been installed in these watersheds over the past ten years was then extrapolated over the next ten years. The basic assumption of this plan is that without additional financial incentives and increased rate of technical assistance, the past ten years' activities serve as a reasonable yardstick of progress for predicting conditions ten years in the future under ongoing programs.

Two other basic assumptions were made in arriving at this plan. First, it was assumed that if a farmstead changed hands, the conservation practices relating to soil erosion control would not necessarily be continued by the new owner. However, it was also assumed that any manure management and milkhouse waste disposal systems installed prior to transfer of ownership would continue to be used by the new owner.

Thus, the phosphorus and sediment yield resulting from excessive erosion will not change markedly between current condition and future without plan because much of the technical assistance provided by the Soil Conservation Service is expended on replanning farms with new owners. However, phosphorus delivered as a result of improper manure management or milkhouse waste disposal can be expected to continue to be reduced at the same rate as it has been over the past ten years.

Manure Management Only Plan

In several of the watersheds improper manure management is responsible for a major share of the phosphorus which reaches water bodies from agricultural sources. Therefore, a plan must be examined to determine how much of the phosphorus loading problem can be resolved by installing only needed manure management systems.

This plan assumes a manure management system is installed on all farms which currently lack one and that, with the system installed, all of the manure generated is spread at the proper time and is incorporated into the soil. This reduces the dissolved phosphorus load by binding it to soil particles.

No additional erosion control practices are included in this plan, and consequently, the erosion, associated sediment and adsorbed phosphorus pollution problems are not abated.

Minimum Phosphorus Plan

This plan minimizes the amount of agricultural source phosphorus available to aquatic plant growth. It is the combination of conservation practices that most reduces the amount of biologically available phosphorus. Reduction of erosion is a secondary consideration; and in

some cases, erosion control practices are foregone because their implementation would increase the available phosphorus coming off the land.

An interesting phenomena is that under some circumstances phosphorus pollution is increased when erosion is reduced. This comes about when land which is in row crops and eroding at an excessive rate is converted to hayland without a corresponding decrease in manure spread there. Erosion is reduced and the adsorbed phosphorus associated with the erosion is reduced. However, the manure applied to row crops is incorporated, and the associated dissolved phosphorus is kept at a minimum. That same manure, spread on hayland, now produces appreciable dissolved phosphorus. Often the increase in dissolved phosphorus was greater than the decrease in available adsorbed phosphorus.

The assumption that all of the dissolved phosphorus and only 20 percent of the adsorbed phosphorus is available for algae growth makes it necessary to reduce adsorbed phosphorus at a rate five times greater than dissolved phosphorus to accomplish the same reduction in bioavailable phosphorus. This is not always possible, especially in cases where there is not enough land left in row crop to allow for incorporation of all the manure produced on the farm.

Minimum Erosion Plan

The plan to minimize erosion emphasizes erosion reduction practices. Reduction of phosphorus delivery is a secondary benefit but is not taken into consideration in the choosing of alternatives which best fit this plan. The combination of conservation practices which most reduce erosion is chosen to be the Minimum Erosion Plan for each watershed.

Since sediment is directly proportional to erosion, this plan also minimizes sediment and, in watersheds where siltation build-up is more of a problem than phosphorus yield, this plan may be the suggested plan.

In other watersheds adsorbed phosphorus associated with the sediment is the major source of available phosphorus, and the plan to minimize erosion is identical with the plan to minimize phosphorus.

Conservation Tillage Plan

Corn is a major item in the feeding regimen of most of the dairy farms in the study watersheds. Therefore, emphasizing a conservation practice that retains corn acreage while reducing erosion would be a reasonable plan to investigate. Conservation tillage, as a practice, has the advantage of allowing the farm operator to reduce erosion on sloping fields without reducing the amount of corn in his crop

rotation. Indeed, in some instances, the amount of corn can even be increased without exceeding acceptable erosion goals.

Conservation tillage is a conservation practice that has gained considerable acceptance in neighboring states and has begun to gain more acceptance in Vermont. This is due not only to the fact that erosion reduction can be achieved without loss of corn yield but because substantial savings in time and energy can be realized with this tillage procedure.

The Conservation Tillage Plan maximizes the use of conservation tillage as a practice. It consists of the alternative that has the most acreage of conservation tillage in each of the watersheds.

Cost Efficient Plan

The cost efficient plan is simply that for which the incremenetal cost of phosphorus reduction is lowest. The incremental cost is the difference in the cost of conservation practices for an alternative and the cost for the alternative with the next greater phosphorus reduction, divided by the change in phosphorus reduction. In some cases where minimum tillage reduces production costs or more valuable crops are added to the rotation, the incremental "cost" is negative, meaning that reducing phosphorus causes an increase in net farm income.

The cost efficient plan does not necessarily reduce erosion to tolerable levels. Phosphorus loss, while reduced, may not be sufficiently curtailed to significantly improve water quality in receiving water bodies. This plan can, however, show a useful intermediate result at low cost.

Suggested Plan

Each of the above plans has a unique goal. By the same token each watershed has its own unique set of problems and needs. The plans were examined to determine which plan best addressed these problems and needs. Reduction of phosphorus loadings and erosion at the least cost were the criteria used in selecting the suggested plan.

Because undesirable plant growth is the predominant water quality problem in Vermont waters and because phosphorus is usually the limiting factor in the plant growth, reduction of phosphorus was given more weight in plan selection than erosion reduction. However, when two or more plans had similar reduction of phosphorus at comparable costs, the plan that most reduced erosion was chosen. In cases where sediment and related adsorbed phosphorus were the major source of phosphorus loadings, the plan that most reduced erosion also most reduced phosphorus yield.

A plan was selected for each watershed according to the problems and needs of that watershed and the criteria mentioned above. This plan was designated as the Suggested Plan for the watershed.

Suggested Plans for the Lake Champlain basin and the Lake Memphremagog basin were developed by aggregating the Suggested Plans for all the watersheds in each basin. Thus, the basin level plans do not represent one management alternative applied basin-wide, but rather a sum of the Suggested Plans for each of the individual watersheds in the basin. Tables 5.2 and 5.3 display the elements of the Suggested Plans for the Lake Champlain and Lake Memphremagog basins, respectively.

ALTERNATIVE BASIN PLANS

Lake Champlain Basin

Agricultural nonpoint source phosphorus loads to Lake Champlain are derived from several key sources on dairy farms. The application of manure to farm fields results in nearly 35,000 pounds of available phosphorus entering the lake annually. In addition, phosphorus losses from manure stacks, barnyards and milkhouse effluent contribute another 35,000 pounds (see Table 4.6). Overall, manure from fields, stacks, barnyards and milkhouse waste contributes 57 percent of the total available phosphorus delivered to the lake.

Winter application of manure creates a substantial water quality hazard because the manure is washed away in spring runoff, often coloring nearby streams dark brown. Barnyards and manure stacks contribute significant phosphorus loads during high runoff events but may also supply phosphorus at other times as well. This is especially true when stacks are found on streambanks or a perennial stream runs through the barnyard. Milkhouse waste piped directly to ditches or water courses also serves as a phosphorus source.

Adsorbed phosphorus losses due to soil erosion contribute the remaining 43 percent (53,000 pounds) of the total available phosphorus reaching Lake Champlain. Practices such as plowing up and down slope, lack of cover crops, and tillage on steep slopes contribute to soil erosion and subsequent phosphorus loadings to the lake. Although erosion may occur during any period soils are not frozen, maximum erosion on cropland occurs in spring before a plant canopy is established.

The following plan alternative descriptions highlight the salient characteristics of each plan. Table 5.2 displays the impacts of the various plans on critical resource concerns in the Champlain basin.

Table 5.2 Summary of Resource Concerns and the Impacts of Alternative Plans in the Study Watersheds of the Champlain Basin.

Resource Concerns	Existing Condition	Future W/O Plan	Manure Only	Min. Phos.	Min. Erosion	Conserv. Tillage	Cost Efficiency	Suggested Plan
			Alternative Plan Reductions 1/					
A. Phosphorus (lbs)								
Cropland Adsorbed	267,250	267,250	0	170,350	171,510	156,740	76,030	155,070
Dissolved 2/	35,010	25,410	14,850	18,290	17,860	18,640	18,600	18,470
Available	88,400	78,860	14,580	52,310	51,630	50,000	34,010	49,830
Forestry 3/ Available	3,960	3,960	160	160	160	160	160	160
Animal Waste 4/ Available	34,980	30,390	22,260	22,480	22,480	22,480	22,480	22,480
B. Erosion								
Cropland Area (Acres)	161,190	161,190	0	1,900	1,900	1,900	1,900	1,900
Total Erosion (Tons)	663,430	663,430	0	423,570	426,300	394,040	192,790	402,010
Forestry 3/ Total Erosion (Tons)	65,410	65,410	2,150	3,670	3,670	3,670	3,670	3,670
C. Sediment (Tons)								
Cropland	97,930	97,930	0	62,780	63,160	58,320	28,000	53,290
Forestry 3/	19,490	19,490	540	1,000	1,000	1,000	1,000	1,000
D. Adequate Animal Waste Systems (No.)			Alternative Plan Increases in BMP's					
Manure Storages	503	684	396	396	396	396	396	396
Barnyards	546	679	401	401	401	401	401	401
Milkhouses	680	776	304	304	304	304	304	304

Table 5.2 (Con't) Summary of Resource Concerns and the Impacts of Alternative Plans in the Study Watersheds of the Champlain Basin.

	Existing Condition	Future W/O Plan	Manure Only	Min. Phos.	Min. Erosion	Conserv. Tillage	Cost Efficiency	Suggested Plan
E. Cropland Practices								
Cons. Tillage (Acres)	1,680	1,680	0	5,320	2,730	16,180	440	8,250
Contour Plowing (Acres)	14,700	14,700	0	12,660	13,570	10,000	3,460	12,470
Contour Strip Plowing (Acres)	960	960	0	20,800	20,860	16,540	3,990	20,840
Conv. to Perm. Hay (Acres)	17,540	17,540	0	5,440	5,160	10,770	840	6,340
Diversions & Terraces (ft)	0	0	0	1,060	1,060	2,340	150	2,350
F. Economics			Alternative Plan Economic Impacts					
Net Farm 5/ Income ($1,000	12,601	12,240	-972 6/	-1,392	-1,373	-1,207	-939	-1,196
Agricultural Installation Cost ($1,000)	0	4,315	6,642	7,202	7,129	7,634	6,735	7,395
Forest Installation Costs ($1,000)		0	0	455	455	455	455	455
Total Installation 7/ Costs ($1,000)		4,315	6,642	7,657	7,584	8,089	7,190	7,850

1/ Changes are measured by substracting plan values from the Future W/O Plan values.
2/ Dissolved P source = field spread manure.
3/ Includes forest land and roads.
4/ Animal waste = manure stacks, barnyard runoff, and milkhouse effluent.
5/ June, 1979.
6/ Negative sign indicates decrease in net farm income.
7/ Installation cost for alternative plans are not of Future W/O Plan cost.

Future Without Plan

The future without plan option assumes the installation of conservation practices will proceed at present rates under existing programs even if none of the plans discussed below are adopted. The ongoing program initiatives to control soil erosion are effective only in preventing further decline in soil loss. The turn-over rate of farm ownership and subsequent change in management precludes real gains in controlling erosion. Current estimates in the Champlain Basin show that 181 manure storage facilities will be installed over the next 10 years. In addition, 133 barnyards will be treated, and 96 milkhouse waste systems will be installed during the same period. Implementing the above practices will reduce available phosphorus loads by 14,130 pounds. Loads from forestland and logging activities are estimated at 3,960 pounds annually. The ongoing program does not address forest related erosion. Implementation of conservation practices will have a small impact on phosphorus loads (see Table 5.2). Overall, this alternative affords no significant improvement in water quality from present conditions. Estimated cost of installation is $4,315,000.

Manure Managment Only Plan

The idea behind this plan is to evaluate the impacts of treating only the dissolved portion of nonpoint agricultural phosphorus loads. Excluding the adsorbed portion of phosphorus permits analysis of the effectiveness of best management practices for treating manure-derived phosphorus. The plan includes a practice mix for treating manure, milkhouse waste and barnyards. Approximately 396 manure storage facilities and 304 milkhouse waste systems are installed. In addition, 401 barnyards are treated. The effect of implementing the best management practices for cropland is the reduction of 36,840 pounds of available phosphorus to the lake.

Although effective in reducing dissolved phosphorus, this plan completely ignores adsorbed phosphorus loadings. Table 4.6 shows that adsorbed phosphorus comprises 43 percent of the total available phosphorus. A comprehensive management plan to control nonpoint source agricultural pollution must, necessarily, include adsorbed phosphorus loads. This plan falls short of providing the necessary integration of farm phosphorus sources needed to effectively protect the water quality of Lake Champlain. Installation costs total $10,957,000.

Minimum Phosphorus Plan

The criteria for defining the environmental quality plan is to reduce total available phosphorus to the greatest extent. The idea of this alternative is to provide maximum environmental protection by minimizing phosphorus loads to the lake. The plan objective is accomplished by implementing 396 manure storage and 304 milkhouse

waste facilities in conjunction with improving 401 barnyards. In addition, the following erosion control measures are applied to cropland: 5,320 acres of conservation tillage; 12,660 acres of contour plowing; 20,800 acres of contour stripcropping; 5,440 acres converted to permanent hay; and diversions to protect 1,060 acres. This mix of best management practices reduces available phosphorus loadings by 74,790 pounds annually. Management of forest roads reduces loadings of phosphorus by another 160 pounds. The total installation cost for this plan is $11,517,000.

Minimum Erosion Plan

Plan criteria for this alternative is least total erosion from cropland. Erosion losses under this plan are cut by 426,000 tons from the ongoing program and sediment loads by 63,000 tons. Plan elements for managing phosphorus include installing the same number of manure management facilities, milkhouse waste systems and barnyard controls as described in the Minimum Phosphorus Plan. Under this plan, conservation tillage is used on 2,730 acres, contour tillage on 13,570 acres and 20,860 acres are contour stripcropped. Conversion to permanent hay occurs on 5,160 acres. Overall, 74,110 pounds of phosphorus reduction occurs with best management practices. Management of forest road erosion reduces phosphorus loads by 160 pounds. Installation costs total $11,444,000.

Conservation Tillage Plan

This plan alternative emphasizes the use of conservation tillage as the first practice employed to control soil erosion. Installation of treatment measures to manage animal waste are identical to those described under Minimum Phosphorus, Minimum Erosion and Cost Efficient plans. A mix of erosion control practices for cropland are installed including the following: 16,180 acres of conservation tillage; 10,000 acres contoured plowed; 16,540 acres of contour stripcropping; 10,770 acres of land converted to permanent sod crop; and 2,340 acres protected with diversions. Implementation of these conservation practices reduces available phosphorus loads 50,000 pounds from cropland and 22,480 pounds from manure stacks, barnyards and milkhouses. This plan relies heavily upon the assumption that conservation tillage would be widely adopted by farmers. Evidence suggests such adoption is unlikely. Management of forest road erosion reduces phosphorus loads by an additional 160 pounds. Installation costs are $11,949,000, the highest among all alternatives.

Cost Efficient Plan

The cost efficient plan selects a composite of conservation practices which provide the largest reduction in phosphorus per unit cost. This plan reduces phosphorus loads 56,490 pounds above that

attained with the ongoing program. The plan elements consist of implementing 396 manure storage facilities, 304 milkhouse waste disposal systems, and improvement of 401 barnyards. Practices designed to control erosion include the installation of 440 acres of conservation tillage, 3,460 acres of contour tillage, 3,990 acres of contour stripcropping, 840 acres of conversion to permanent hay and 150 acres protected with diversions. Additionally, forest road practices to control erosion reduce phosphorus loads by 160 pounds annually. Total installation costs for this plan are $11,050,000.

Suggested Plan

This plan consists of implementing best management practices to control phosphorus loads from soil erosion and animal waste. Erosion losses from cropland are cut by 402,010 tons annually corresponding to a 53,290-ton reduction in sediment loads. Management of cropland erosion is accomplished through the installation of 8,250 acres of conservation tillage, 12,470 acres of contour plowing, 20,840 acres of contour stripcropping. In addition, 6,340 acres are converted to permanent hay and 2,350 acres protected with diversions. These best management practices cut available phosphorus loads by 31,360 pounds annually. In total, available phosphorus is reduced by 43 percent through lower sediment loads. Management of logging skid trails provides an additional reduction of 160 pounds of available phosphorus. Animal waste management accounts for nearly 57 percent of the total available phosphorus reduction. This level of achievement is the result of implementing 396 manure storage and 304 milkhouse waste facilities in conjunction with improving 401 barnyards. Installation costs total $11,710,000. A more detailed discussion of this plan is found in Chapter 6.

Lake Memphremagog Basin

As in the Lake Champlain basin, nonpoint phosphorus loadings attributable to agricultural sources are derived primarily from animal waste and sediment from cropland.

Poor animal waste management is the major source of available phosphorus reaching the water bodies from agricultural sources. Improper manure spreading practices and uncontrolled runoff from barnyards are the principle causes. Each contributes 35 percent of the total available phosphorus from agricultural nonpoint sources. Manure stacks contribute 10 percent of the available phosphorus and milkhouse wastes account for another 3 percent. In all, improper animal waste management accounts for 83 percent of all the available phosphorus reaching Lake Memphremagog from nonpoint agricultural sources.

Phosphorus adsorbed to soil particles coming off eroding lands contributes the remaining 17 percent of available phosphorus from nonpoint agricultural sources.

Obviously, the emphasis in the Lake Memphremagog basin should be directed toward reducing the loadings derived from improper animal waste management. However, erosion from cropland cannot be ignored.

The effects of the seven alternative plans formulated for the basin are depicted in Table 5.3 and discussed as follows.

Future Without Plan

As described in the section above dealing with the Lake Champlain basin, the first option to be investigated in the Lake Memphremagog basin was the "business as usual" alternative.

Again, due to turnover of farm ownership in the basin, the ongoing farm planning efforts are not effecting an appreciable reduction in soil erosion. When a farm changes hands, the new manager will most likely have different management procedures and objectives, and the farm must be replanned to meet these objectives while minimizing soil erosion. Without an accelerated effort, the funds and expertise available to aid in proper farm planning should keep pace with this need for replanning; but there will be little left over for reducing soil erosion below current levels. Therefore, the erosion rate and the associated sediment and adsorbed phosphorus is assumed to remain the same in the future without plan as in current conditions.

Dissolved phosphorus resulting from improper animal waste treatment can be expected to decrease in the future without accelerated assistance, however. This is because systems designed and implemented to treat animal wastes usually include relatively permanent structural measures which change hands with the farm and are most likely to be continued in use. For this reason, the future without plan option assumes that installation of animal waste facilities will continue at the current rate and the associated dissolved phosphorus runoff will be reduced accordingly. The contribution of dissolved phosphorus to Lake Memphremagog from animal waste sources should be reduced 1,900 pounds or 23 percent over the next 10 years with a total installation cost of $541,000 (see Table 5.3).

Manure Management Only Plan

This plan represents the first increment of treatment. It concentrates on reducing the dissolved phosphorus derived from animal wastes. Milkhouse waste treatment systems are included in this plan because incorporation of milkhouse waste into the manure management system is often the most efficient and least costly method of handling the entire animal waste management problem. Approximately 30 manure storage facilities, 15 milkhouse waste systems and 80 barnyard drainage systems would be installed under this plan. These numbers of practices would be in addition to those facilities which might be expected to be installed under ongoing programs.

Table 5.3 Summary of Resource Concerns and the Impacts of Alternative Plans in the Study Watersheds of the Memphremagog.

Resource Concerns	Existing Condition	Future W/O Plan	Manure Only	Min. Phos.	Min. Erosion	Conserv. Tillage	Cost Efficiency	Suggested Plan
			Alternative Plan Reductions 1/					
A. Phosphorus (lbs)								
Cropland								
Adsorbed	8,339	8,339	0	5,074	5,094	5,074	3,417	5,094
Dissolved 2/	3,486	2,894	1,149	1,082	961	1,082	1,133	961
Available	5,154	4,561	1,149	2,046	1,979	2,096	1,815	1,979
Forestry 3/								
Available	1,020	1,020	130	130	130	130	130	130
Animal Waste 4/								
Available	4,872	3,552	3,053	3,053	3,053	3,053	3,053	3,053
B. Erosion								
Cropland								
Area (Acres)	23,252	23,252	0	0	0	0	0	0
Total Erosion (Tons)	25,989	24,989	0	15,254	15,572	15,254	10,279	15,295
Forestry 3/								
Total Erosion (Tons)	15,385	15,385	0	754	754	754	754	754
C. Sediment (Tons)								
Cropland	2,861	2,861	0	1,679	1,713	1,679	454	1,683
Forestry 3/	4,575	4,575	0	188	188	188	188	188

Table 5.3 (Con't) Summary of Resource Concerns and the Impacts of Alternative Plans in the Study Watersheds of the Memphremagog.

	Existing Condition	Future W/O Plan	Manure Only	Min. Phos.	Min. Erosion	Conserv. Tillage	Cost Efficiency	Suggested Plan
D. Adequate Animal Waste Systems (No.)			Alternative Plan Increases in BMP's					
Manure Storages	167	185	33	33	33	33	33	33
Barnyards	108	136	82	82	82	82	82	82
Milkhouses	170	205	13	13	13	13	13	13
E. Cropland Practices								
Cons. Tillage (Acres)	0	0	0	1,337	103	1,337	639	899
Contour Plowing 5/ (Acres)	1,503	1,503	0	-134	-125	-134	0	-20
Contour Strip Plowing (Acres)	96	96	0	374	574	374	0	269
Conv. to Perm. Hay (Acres)	0	0	0	68	68	68	0	68
Diversions & Terraces (ft)	0	0	0	160	0	160	0	0

Table 5.3 (Cont'd) Summary of Resource Concerns and the Impacts of Alternative Plans in the Study Watersheds of the Memphremagog.

	Existing Condition	Future W/O Plan	Manure Only	Min. Phos.	Min. Erosion	Conserv. Tillage	Cost Efficiency	Suggested Plan
F. Economics			Alternative Plan Economic Impacts					
Net Farm 6/ Income ($1,000)	1,234	1,152	-169 7/	-197	-187	-197	-168	-188
Agricultural Installation Cost ($1,000)	0	794	807	876	815	876	822	840
Forest Installation Cost ($1,000)	0	0	0	107	107	107	107	107
Total Installation 8/ Cost ($1,000)	0	794	807	983	922	983	929	947

1/ Changes are measured by substracting plan values from the Future W/O Plan values.
2/ Dissolved P source = field spread manure.
3/ Includes forest land and roads.
4/ Animal waste = manure stacks, barnyard runoff, and milkhouse effluent.
5/ Negative sign indicates a decrease in contour plowing.
6/ June, 1979.
7/ Negative sign indicates decrease in net farm income.
8/ Installation cost for alternative plans are net of future W/O plan cost.

All plans except the Future Without Plan assume that 80 miles of forest roads would be adequately treated to reduce available phosphorus by 130 pounds.

Dissolved phosphorus from cropland would be reduced by 1,150 pounds because, with storage facilities, the manure can be spread at the proper time and be incorporated into the soil at the time of application. In addition, treatment of manure stacks, barnyard runoff and milkhouse effluent would reduce dissolved phosphorus runoff by 3,050 pounds. Again, this phosphorus reduction would be over and above that which might be expected under ongoing programs. The estimated installation costs for this plan is $1,108,000, or $567,000 more than the Future Without Plan.

Minimum Phosphorus Plan

The growth of undesirable aquatic plants and periodic algal blooms in the Vermont portion of Lake Memphremagog constitute the greatest environmental problem of the lake. Phosphorus is the limiting nutrient to this plant growth; and consequently, the plan that greatest reduces phosphorus runoff from the agricultural lands is considered the environmental quality plan.

The mix of conservation practices that constitute this plan brings all cropland erosion down to tolerable limits and, thereby, reduces adsorbed phosphorus loadings associated with erosion and sediment by 5,070 pounds.

The same mix of practices for animal waste management are applied in the Minimum Phosphorus Plan as were employed in the Manure Management Only Plan. These practices reduce dissolved phosphorus runoff by 4,260 pounds. The slight difference between the dissolved phosphorus reduction in this plan and the Manure Management Only Plan is due to changes in cropping rotation which were employed to reduce erosion to tolerable limits. In all, this plan reduces the total phosphorus available for plant growth by 5,280 pounds at an estimated installation cost of $1,177,000, or $636,000 more than the Future Without Plan.

Minimum Erosion Plan

This plan consists of a mix of conservation practices which results in a minimum of erosion and resulting siltation coming from cropland in the basin. Since adsorbed phosphorus is associated with the soil particles, this plan also has the greatest reduction in adsorbed phosphorus, 5,090 pounds. However, the extra reduction in erosion and adsorbed phosphorus comes at the expense of dissolved phosphorus. Dissolved phosphorus is reduced 4,140 pounds over what might be expected without a plan, but this is about 120 pounds more than might be expected from the Minimum Phosphorus Plan. Under this

plan total erosion would be reduced by 15,570 tons and total available phosphorus would be reduced by 5,160 pounds. The estimated cost of installation is $1,116,000, or $575,000 more than the Future Without Plan.

Conservation Tillage Plan

A management plan that maximizes the use of conservation tillage as a conservation practice was developed for each watershed in the study. It allows the farmer to reduce erosion and related sediment and phosphorus runoff while still maintaining existing cropping patterns, in many cases. In the Lake Memphremagog basin, coincidentally, the conservation tillage plan was also the plan that most reduced phosphorus. It is described above as the Minimum Phosphorus Plan.

Cost Efficient Plan

As mentioned previously in the report, the most cost efficient plan consists of a mix of conservation practices that reduces phosphorus yields at the least cost per pound of reduction. Since the emphasis of this study is on water quality, other conservation concerns were not taken into account when selecting the most cost efficient plan. For this reason the plan allows for 161 acres in the Memphremagog basin to continue to erode at a rate that would eventually deplete the soil resource base. Available phosphorus runoff would be reduced by 5,000 pounds under this plan at an estimated installation cost of $1,123,000, or $582,000 more than the Future Without Plan. Moreover, net farm income in the basin would be adversely affected least by this plan of all the plans developed.

Suggested Plan

As mentioned previously in the report, the suggested plan consists of an aggregate of conservation practices in each of the watersheds in the basin that maximize reduction of erosion and phosphorus delivery at the least cost. It falls somewhere between the plans described above.

Erosion is reduced to allowable limits to preserve the soil resource base in each watershed. Total erosion in the basin is reduced by 15,300 tons and available phosphorus is reduced by 1,980 pounds at an estimated installation cost of $1,141,000 ($600,000 more than Future Without Plan). Table 5.3 displays the conservation practices and their effects on crops, erosion, phosphorus and sediment yield and farm incomes for each of the plans presented.

Harvey's Lake

Agricultural nonpoint source phosphorus loadings to Harvey's Lake originate from eroding soils, dairy manure and milkhouse waste. Approximately 580 pounds of available phosphorus enters the lake as the result of sheet and rill erosion on cropland. Another 460 pounds of available phosphorus is derived from manure applied to fields, run-off from manure stacks and barnyards and milkhouse waste. Field applied manure and barnyards provide 76 percent or 350 pounds of the 460 pounds of available phosphorus mentioned above (see Table 4.8). Pastures may provide slight loads from erosion and cattle spread manure. Forestry operations produce slight phosphorus loads with management of logging roads providing minute reductions in watershed wide loadings.

Table 5.4 displays the impacts of the various plan alternatives on resource concerns critical to the Harvey's Lake Watershed. The reader is referred to the above description of the Lake Champlain basin for a general description of each individual plan. Details specific to each plan for Harvey's Lake are outlined in the description below.

Future Without Plan

The ongoing program provides limited reduction in available phosphorus. Manure management provides approximately 40 pounds of phosphorus reduction annually. No net gain in erosion reduction is achieved with this plan. Phosphorus loads from forestry remain unchanged. Installation costs total $38,000.

Manure Management Only Plan

Available phosphorus loads are reduced by 240 pounds with the installation of nine manure storage facilities. Phosphorus reductions are the result of: avoiding winter application of manure and stacking, cleaning up barnyards and managing milkhouse waste effluent. Installation costs total $66,000.

Minimum Phosphorus Plan

Available phosphorus contributions from agriculture are reduced by 670 pounds through implementing a variety of practices including: nine manure storage facilities, treating seven barnyards and nine milkhouse waste systems. Conservation tillage occurs on 27 acres with contour plowing and stripcropping applied to 125 and 192 acres, respectively. Installation costs total $68,000.

Table 5.4 Summary of Resource Concerns and the Impacts of Alternative Plans in Harvey's Lake Watershed.

Resource Concerns	Existing Condition	Future W/O Plan	Manure Only	Min. Phos.	Min. Erosion	Conserv. Tillage	Cost Efficiency	Suggested Plan
			Alternative Plan Reductions 1/					
A. Phosphorus (lbs)								
Cropland								
Adsorbed	2,900	2,900	0	2,240	2,240	2,160	1,080	2,160
Dissolved 2/	170	130	40	20	20	40	40	40
Available	750	710	40	470	470	470	260	480
Forestry 3/								
Available	60	60	0	0	0	0	0	0
Animal Waste 4/								
Available	290	280	200	200	200	200	200	200
B. Erosion								
Cropland								
Area (Acres)	1,220	1,220	0	0	0	0	0	0
Total Erosion (Tons)	4,690	4,690	0	3,620	3,620	3,470	1,760	3,470
Forestry 3/								
Total Erosion (Tons)	1,020	1,020	30	30	30	30	30	30
C. Sediment (Tons)								
Cropland	940	940	0	730	730	700	350	700
Forestry	310	310	10	10	10	10	10	10
D. Adequate Animal								
			Alternative Plan Increases in BMP's					
Waste Systems (No.)								
Manure Storages	6	6	9	9	9	9	9	9
Barnyards	8	8	7	7	7	7	7	7
Milkhouses	6	6	9	9	9	9	9	9

Table 5.4 (Con't) Summary of Resource Concerns and the Impacts of Alternative Plans in Harvey's Lake Watershed.

	Existing Condition	Future W/O Plan	Manure Only	Min. Phos.	Min. Erosion	Conserv. Tillage	Cost Efficiency	Suggested Plan
E. Cropland Practices								
Cons. Tillage (Acres)	0	0	0	30	30	280	0	280
Contour Plowing (Acres)	100	100	0	30	30	40	0	40
Contour Strip Plowing (Acres)	0	0	0	190	190	30	0	30
Conv. to Perm. Hay (Acres)	0	0	0	0	0	15	0	15
Diversions & Terraces (ft)	0	0	0	0	0	10	0	10
F. Economics			Alternative Plan Economic Impacts					
Net Farm Income 5/	169,000	165,000	-7,100 6/	-9,000	9,000	-8,600	-1,700	-8,600
Installation Costs	0	38,000	66,000	68,000	68,000	73,000	66,000	73,000
Forest Installation Costs		0	0	7,000	7,000	7,000	7,000	7,000
Total Installation Costs 7/		38,000	28,000	30,000	30,000	35,000	28,000	35,000

1/ Changes are measured by subtracting plan value from the Future W/O Plan values.
2/ Dissolved P Source = field spread manure.
3/ Includes forest land and roads.
4/ Animal waste = manure stacks, barnyard runoff and milkhouse effluent.
5/ June, 1979.
6/ Negative sign indicates a decrease in net farm income.
7/ Installation cost for alternative plans are net of Future W/O Plan cost.

Minimum Erosion Plan

Plan elements including cropping practices, phosphorus reductions and costs are identical to those listed under the Minimum Phosphorus Plan.

Conservation Tillage Plan

Available phosphorus is reduced by approximately 670 pounds with this plan alternative. Phosphorus lost from cropland erosion is controlled through installing 282 acres of conservation tillage, 40 acres of contour plowing, 29 acres of contour stripcropping, conversion of 15 acres to permanent hay, and installing diversions to protect 10 acres. Plan elements to control phosphorus losses from manure are identical to those listed in the Minimum Phosphorus Plan described earlier. Total installation cost equals $73,000.

Cost Efficient Plan

Reductions in available phosphorus total 460 pounds with this alternative. Cropland practices to control soil derived phosphorus include only contour plowing. Plan elements for manure management are identical to the Minimum Phosphorus Plan. Total installation costs are $66,000.

Suggested Plan

Best management practices reduce available phosphorus by 680 pounds annually. Soil derived phosphorus is reduced approximately 440 pounds through the installation of 280 acres of conservation tillage, 40 acres of contour plowing, 30 acres of contour stripcropping, conversion of 15 acres to permanent hay and diversions to protect 10 acres. Managing animal waste provides an additional reduction of 240 pounds. The plan calls for nine manure storage facilities and milkhouse waste systems installed and seven barnyards treated for excessive runoff. Installation costs total $73,000.

Shelburne Pond

Agricultural nonpoint source phosphorus loadings to Shelburne Pond occur predominantly, but not exclusively, from animal waste. Approximately 760 pounds (90 percent) of the total available phosphorus currently lost from the watershed is derived from animal waste. Soil erosion contributes 9 percent of the available phosphorus load. Background loads from forest sources provide an additional eight pounds of available phosphorus yearly.

Table 5.5 displays the impacts of the various plan alternatives on resource concerns critical to the Shelburne Pond Watershed. The reader is directed to the above description of the Lake Champlain basin for a general description of each individual plan. Details specific to each plan for Shelburne Pond are outlined in the description below.

Future Without Plan

Total available phosphorus is reduced 150 pounds through installation of one of each of the following: manure storage facility, barnyard systems and milkhouse waste system. Cropland erosion remains unchanged from current condition, consequently phosphorus losses from erosion are not reduced under ongoing program measures.

Manure Management Only Plan

Total available phosphorus is reduced 230 pounds annually through controlling phosphorus losses from animal waste. Under this plan, three manure storage facilities and one each of milkhouse waste and barnyard runoff systems are installed. Total installation cost equals $69,000.

Minimum Phosphorus Plan

Annual reduction of available phosphorus totals 240 pounds. The major portion of the reduction, 236 pounds, is accomplished through implementing the same type and number of best management practices for manure management as described in the Manure Management Only Plan above. Control of soil erosion through contour plowing eight acres provides an additional reduction of four pounds of available phosphorus. Installation costs total $69,000.

Minimum Erosion Plan

The minimum erosion alternative contains the same plan elements and installation costs as the Minimum Phosphorus Plan. Phosphorus reductions are likewise identical.

Conservation Tillage Plan

Overall available phosphorus loads are cut by 214 pounds with this alternative. Manure storage facilities are installed on three farms and barnyard and milkhouse waste systems applied to one farm. Available phosphorus reduction from implementing manure management practices totals 240 pounds. Measures to control soil erosion include

Table 5.5 Summary of Resource Concerns and the Impacts of Alternative Plans in Shelburne Pond Watershed.

Resource Concerns	Existing Condition	Future W/O Plan	Manure Only	Min. Phos.	Min. Erosion	Conserv. Tillage	Cost Efficiency	Suggested Plan
				Alternative Plan Reductions 1/				
A. Phosphorus (lbs)								
Cropland								
Adsorbed 2/	380	380	0	20	20	+130 3/	+110	0
Dissolved	260	150	60	60	60	70	70	60
Available	340	230	60	70	70	50	50	50
Forestry 4/								
Available	10	10	0	0	0	0	0	0
Animal Waste 5/								
Available	250	210	170	170	170	170	170	170
B. Erosion								
Cropland								
Area (Acres)	990	990	0	0	0	0	0	0
Total Erosion (Tons)	670	670	0	40	40	+40	+70	0
Forestry 4/								
Total Erosion (Tons)	130	130	0	0	0	0	0	0
C. Sediment (Tons)								
Cropland	150	150	0	10	10	+40	+40	0
Forestry 4/	40	40	0	0	0	0	0	0
D. Adequate Animal Waste Systems (No.)								
			Alternative Plan Increases in BMP's					
Manure Storages	4	5	3	3	3	3	3	3
Barnyards	6	7	1	1	1	1	1	1
Milkhouses	7	8	1	1	1	1	1	1

Table 5.5 (Con't) Summary of Resource Concerns and the Impacts of Alternative Plans in Shelburne Pond Watershed.

	Existing Condition	Future W/O Plan	Manure Only	Min. Phos.	Min. Erosion	Conserv. Tillage	Cost Efficiency	Suggested Plan
E. Cropland Practices								
Cons. Tillage (Acres)	0	0	0	0	0	0	0	0
Contour Plowing (Acres)	205	205	0	8	8	8	0	0
Contour Strip Plowing (Acres)	0	0	0	0	0	0	0	0
Conv. to Perm. Hay (Acres)	0	0	0	0	0	0	0	0
Diversions & Terraces (ft)	0	0	0	0	0	0	0	0
F. Economics			Alternative Plan Economic Inputs					
Net Farm Income 6/	107,000	106,000	7/ -2,100	-2,100	-2,100	-200	-200	-2,100
Agricultural Installation Costs	0	30,000	69,000	69,000	69,000	69,000	69,000	69,000
Forest Installation Costs	0	0	0	990	990	990	990	990
Total Installation Costs 8/	0	30,000	39,000	39,990	39,990	39,990	39,990	39,990

1/ Changes are measured by subtracting plan values from the Future W/O Plan values.
2/ Dissolved P source = field spread manure.
3/ Plus signs (+) indicate additions above Future W/O Plan conditions.
4/ Includes forest land and roads.
5/ Animal waste = manure stacks, barnyard runoff, and milkhouse effluent.
6/ June, 1979.
7/ Negative sign indicates a decrease in net farm income.
8/ Installation cost for alternative plans are net of Future W/O Plan cost.

eight additional acres of contour plowing above the ongoing program estimates. Total erosion, however, increases due to mitigation effect on corn land (see SCS, 1982). This contributes approximately 26 pounds of available phosphorus to receiving waters annually. Soil limitations preclude implementing conservation tillage on any fields in this watershed, consequently the methodology for computing best management practices defaults to conventional tillage methods. Installation costs total $69,000.

Cost Efficient Plan

Management of animal waste, through implementation of a mix of practices identical to the Manure Management Only Plan, reduces available phosphorus by 220 pounds. Soil derived available phosphorus increases by 22 pounds due to mitigation effects. However, overall management combines to reduce available phosphorus by 198 pounds. Installation costs total $69,000.

Suggested Plan

The suggested plan for the Shelburne Pond Watershed is the Manure Management Only Plan. Erosion is slight and does not justify the cost of practices to reduce phosphorus loads.

CHAPTER 6

THE SUGGESTED PLAN AND

ITS OFFSITE EFFECTS

The Suggested Plan is discussed as the last of the alternatives for each of the basins in Chapter 5. The suggested plan contains a balanced mix of practices that reduce phosphorus loads, minimize economic impacts and are feasible to implement. This chapter covers the treatment elements required by the plan for each of the WQMA's, resulting phosphorus load reductions to the WQMA's, the significance of each WQMA for agricultural nonpoint source management and the sensitivity of each WQMA to watershed protection efforts.

EFFECTS OF PLAN BY WQMA's

Impacts of the plan on phosphorus loads to the various water quality management areas (WQMA's) are depicted in Table 6.1 below. Practices used to control soil erosion and manage manure are shown in Table 6.2.

Missisquoi Bay

Total phosphorus loads from agriculture are reduced by 28,900 pounds or 59 percent with implementation of the Suggested Plan. Available phosphorus loads drop by 10,900 pounds corresponding to a 58 percent reduction. To accomplish this reduction, the plan relies heavily upon installing 590 acres of contour stripcropping. Additionally, 71 acres of conservation tillage, 55 acres of contour plowing and conversion of 9 acres to permanent hay are needed. Soil erosion from forest roads is reduced through management of 81 miles of logging roads. To manage dissolved phosphorus losses from animal waste sources, 82 manure storage facilities are installed. Also, practices to reduce runoff from 69 barnyards and systems for managing milkhouse waste from 59 milkhouses are installed.

Malletts Bay

Total phosphorus loads derived from Malletts Bay Watershed are reduced 6,300 pounds or 55 percent through installation of best management practices. A majority of this reduction occurs through reducing dissolved phosphorus losses from animal waste. The plan calls for the installation of 23 manure storage systems, improved management of 30 barnyards and construction of 14 milkhouse waste systems. Soil-related phosphorus losses are decreased by increasing contour tillage by 466 acres and contour stripcropping by 148 acres. These practices are effective in reducing sediment loads to the Bay by cutting cropland erosion.

Table 6.1 Impacts of Suggested Plan on Phosphorus Reduction in the Various Water Quality Management Areas 1/

	Adsorbed Phos. Percent Reduction 2/	Dissolved Phos. Percent Reduction	Total Phos. Percent Reduction	Available Phos. Percent Reduction
Missisquoi	60	60	60	59
Malletts Bay	70	67	70	69
Central Main Lake	44	80	53	66
South Main Lake	58	78	60	64
South Lake	53	74	55	60
Memphremagog	61	33	54	43
Shelburne Pond	0	40	12	27
Harveys Lake	74		73	69

1/ Results of this table were compiled from: Quantification of Resources and Problems in Vermont Agricultural Runoff Study Watersheds,, Vermont Ag. Runoff Technical Report No. 5, Soil Conservation Service, USDA, Burlington, Vermont, October 1982

2/ Percent change equals difference between the Future W/O and Suggested Plans divided by the Future W/O Plan

Table 6.2 Description of Best Management Practices in the Suggested Plan.

	Cropland Practices					Manure Management Practices			Forest Practices
	Cons. Tillage	Contour Plow	Contour Strip Plow	Conv. Perm. Hay	Diversions	Storage Systems	Barnyards	Milkhouse Waste System	Managed Forest Roads
	Acres					Number			Miles
MISSISQUOI BAY									
Ongoing	637	3,024	193	1,774	0	241	254	264	81
Recommended	1,089	4,693	1,333	1,928	0	323	323	323	81
Difference									
number 1/	452	1,669	1,140	154	0	82	69	59	0
percent change	71	55	590	9	0	34	27	22	0
MALLETTS BAY									
Ongoing	0	280	0	0	0	33	26	42	35
Recommended	0	746	148	148	0	56	56	56	35
Difference									
number	0	466	148	0	0	23	30	14	0
percent change	0	166		-	0	70	115	33	0
CENTRAL MAIN LAKE									
Ongoing	1,045	1,974	133	51	0	24	27	33	53
Recommended	1,288	980	412	103	6	42	42	42	53
Difference									
number	243	-994	279	52	6	18	15	9	0
percent change	23	-50	210	102	-	75	56	27	0
SOUTH MAIN LAKE									
Ongoing	0	5,859	389	13,603	0	340	326	383	145
Recommended	7,907	16,474	17,960	18,786	2,268	562	562	562	145
Difference									
number	7,907	10,615	17,571	5,183	2,268	222	236	178	0
percent change	-	181	451	38	-	65	72	47	0

1/ Percent change equals difference between ongoing and suggested plans divided by the ongoing plan value.

Table 6.2 (Con't) Description of Best Management Practices in the Suggested Plan.

	Cropland Practices					Manure	Management	Practices	Forest Practices
	Cons. Tillage	Contour Plow	Contour Strip Plow	Conv. Perm. Hay	Diversions	Storage Systems	Barnyards	Milkhouse Waste System	Managed Forest Roads
	Acres					Number			Miles
SOUTH LAKE									
Ongoing	0	3,357	240	2,108	0	54	53	64	39
Recommended	161	4,119	1,945	3,066	78	106	106	106	39
Difference									
number	161	762	1,705	958	78	53	53	43	0
percent change	-	23	710	45	-	98	100	67	0
HARVEY'S LAKE									
Ongoing	0	100	0	0	0	6	8	6	5
Recommended	282	140	29	15	10	15	15	15	5
Difference									
number	282	40	29	15	10	9	7	9	0
percent change	-	40	-	-	-	150	117	150	0
SHELBURNE POND									
Ongoing	0	205	0	0	0	5	7	8	1
Recommended	0	205	0	0	0	8	8	8	1
Difference									
number	0	0	0	0	0	3	1	0	0
percent change	0	0	0	0	0	60	14	0	0

1/ Percent change equals difference between ongoing and Suggested Plans divided by the ongoing plan value.

Central Main Lake

Management of nonpoint source phosphorus loads from agriculture effectively diminish total phosphorus loads by 4,500 pounds annually. This represents a 53 percent reduction. Predominant phosphorus reductions occur from reducing dissolved loads derived from animal waste. Plan components include construction of 18 manure storage facilities and 9 milkhouse waste systems. Barnyard improvement occurs on 15 farms. Cropland management practices include installing 243 acres of conservation tillage, 279 acres of contour stripcropping, 52 acres of permanent hay and protection of 6 acres with diversions.

South Main Lake

Agricultural sub-basins feeding the South Main Lake WQMA provide 251,000 pounds of total phosphorus yearly. This portion of the lake receives the largest phosphorus loads from six sub-basins and portions of another. Adsorbed phosphorus contributes 82 percent (206,000 pounds) of the total phosphorus loadings. Easily eroded, fine textured soils which characterize a large portion of the Champlain subbasin account for this large percentage. An array of practices are installed to protect cropland against soil erosion. Contour tillage is used on 10,600 acres, and contour stripcropping is placed on an additional 18,000 acres of cropland. Approximately 5,200 acres of row cropland is converted to permanent hay. Diversions are installed to protect 2,300 cropland acres. The combined effect of implementing the above practice mix is a reduction of 111,000 pounds of total phosphorus corresponding to a 54 percent reduction. The remaining portion of total phosphorus load is associated with animal waste. Dissolved phosphorus loadings under the ongoing program total 45,000 pounds annually. This figure is dropped to 19,000 pounds by installing 222 manure storage facilities, improving 236 barnyards and constructing 178 milkhouse waste systems. Overall, best management practices reduce total phosphorus loads by 148,000 pounds or 59 percent.

South Lake

Total phosphorus loads from agricultural sources are reduced by 19,200 pounds or 51 percent. In terms of available phosphorus, soil erosion and animal waste provide roughly the same amount — 3,200 and 3,400 pounds, respectively. Control of soil erosion is accomplished through installation of 760 acres of contour tillage and 1,705 acres of contour stripcropping. In conjunction, 958 acres are converted to permanent hay, and 78 acres are protected with diversions. Manure storage facilities are installed on 53 farms and milkhouse waste systems on 43 farms. Barnyard improvement occurs on 5 farms. The above practices combined reduce available phosphorus by 6,600 pounds or 59 percent.

Lake Memphremagog

The plan reduces agricultural source phosphorus loads to Newport Bay by 7,030 pounds (54 percent) annually. This is accomplished through complementing the ongoing program with an addition 899 acres of conservation tillage, 299 acres of contour stripcropping, 68 acres of cropland conversion to hay, 33 animal waste storage structures, 82 barnyard water management systems, 13 milkhouse waste systems and 71 miles of forest road treatment.

Shelburne Pond

Limiting agricultural phosphorus loadings to Shelburne Pond is accomplished primarily by managing animal waste. Manure storage facilities are constructed on three farms along with one milkhouse waste system. The combined effect of best management practices is a reduction of 240 pounds of available phosphorus.

Harvey's Lake

Best management practices in Harvey's Lake Watershed cut total phosphorus loads by 2,500 pounds corresponding to a 73 percent reduction. Cropland erosion practices used to curtail adsorbed phosphorus losses include 282 acres of conservation tillage, 40 ares of contour plowing, and 29 acres of contour stripcropping. Permanent conversions of row crop to hay is recommended on fifteen acres; in addition, ten acres are protected with diversions. Nine manure storage and milkhouse waste systems are installed. Barnyard management occurs on seven farms. Available phosphorus reductions total 700 pounds or 56 percent under the Suggested Plan.

SIGNIFICANCE OF WATER QUALITY MANAGEMENT AREAS

In developing priorities for management of nonpoint source runoff in agricultural watersheds, the significance of the receiving waters must be considered as well as the magnitude of loadings and potential for control within the individual watersheds. In this section key characteristics of each WQMA are compared. Watersheds contributing to each WQMA are also compared. With this information the context of each watershed as a pollutant contributor to a WQMA will be more apparent for assigning priorities and developing individual watershed plans.

One indication of the eutrophication problem in each WQMA is the volume of public complaints received. The Vermont Department of Water Resources has documented these (Garrison, 1982) for Harvey's Lake, Mallett's Bay, Lake Memphremagog, Missisquoi Bay, the South Main Lake and Shelburne Pond. These are listed in descending priority order.

Recreational use is another important WQMA factor. Estimates of potential use are shown in Table 6.3 and are expressed in terms of total potential annual users and annual users per square mile of water surface for existing public facilities only.

Shoreline property value is an important WQMA factor. Values presented here are averages of unimproved front footage based on tax valuations and recent sales in the area. Shoreline values appear to be influenced by at least three major factors. Shoreline values correlate well with the trophic condition of the WQMA -- generally lower shoreline values occur in more eutrophic stretches of the lakes. Proximity of user to the WQMA increases the shoreline value. In some locations shoreline is preferred for year-round residency and, therefore, has a higher value. Table 6.3 provides estimates of shoreline value for each WQMA.

Physical features are significant to the trophic state behavior of the WQMA. Some of the more important parameters are mean depth, annual runoff volume per unit of surface area and flushing rate. These vary in significance by season, particularly for the stratified water bodies. Flushing rate has been chosen to represent these parameters in ranking the WQMA's in Table 6.3.

Table 6.3 provides a qualitative ranking of each WQMA based only on the characteristics contained in the table. Other traits need to be considered by the manager in assigning priorities to the WQMA's for protection from agricultural runoff. However, the table should be helpful in making that determination.

SENSITIVITY OF WATER QUALITY MANAGEMENT AREAS TO STUDY WATERSHEDS

The preferred approach to determining the trophic state sensitivity of various WQMA's to changes in pollutant runoff from agricultural watersheds of the study is the use of reliable predictive modeling. Unfortunately, reliable models which could be used for estimating effects on various WQMA's of Lake Champlain are not available. Resources beyond the scope of this study would be required to set up such models. In lieu of modeling, sensitivity has been appraised on the basis of qualitative criteria for WQMA's in Lake Champlain, Shelburne Pond and Harvey's Lake. Fortunately, the Vermont Department of Water Resources has accelerated a modeling analysis of Lake Memphremagog which assesses the effectiveness of both point and nonpoint source phosphorus management in improving the Lake's water quality. This provides a detailed analysis of Lake Memphremagog's response to scenarios of point and nonpoint source phosphorus control. The results of this analysis are discussed later in this chapter. Qualitative criteria will be used throughout to evaluate the sensitivity of WQMA's to study watersheds.

Table 6.3 Rank of WQMA's by Selected Characteristics

Lake	WQMA	Daily Potential Recreational Use: Users	(Rank)	Users/Mile^2	(Rank)	Dollars Per Foot of Lake Shoreline	(Rank)	Rank by Public Concern 2/	WQMA Flushing Rate, times per year	(Rank)	Sum of ranks	Overall rank 1/
Champlain												
	Central Main	12,220	(1)	121	(4)	500	(1)	(5)	0.4	(1)	(12)	1
	Malletts Bay	11,290	(2)	540	(2)	355	(2)	(2)	1.4	(4)	(12)	2
	Missisquoi Bay	2,430	(4)	82	(6)	140	(5)	(4)	6.1	(7)	(26)	6
	South	1,277	(6)	58	(7)	130	(7)	(7)	8.2	(8)	(35)	7
	South Main	4,110	(3)	109	(5)	270	(3)	(6)	1.1	(3)	(20)	4
Memphremagog	Newport Bay & Vermont Portion of South Basin	2,120	(5)	215	(3)	138	(6)	(3)	2.2	(6)	(23)	5
Shelburne	Entirety	30	(8)	43	(8)	100	(8)	(8)	1.8	(5)	(37)	8
Harveys	Entirety	1.056	(7)	1,760	(1)	150	(4)	(1)	0.5	(2)	(15)	3

1/ In case of ties, the larger WQMA has priority

2/ Per Garrison, et al, Vermont Department of Water Resources

The qualitative criteria to be used are:

(1) the watershed's agricultural nonpoint source phosphorus as a percent of the estimated total phosphorus load to the WQMA (importance increases with percent);

(2) the distance of the watershed outlet from the WQMA in miles (importance decreases with increasing mileage);

(3) the agricultural nonpoint source phosphorus control cost per pound of total phosphorus.

These factors are displayed by each WQMA in Table 6.4

A rank has been assigned as the order of significance (based on Table 6.4 data) of each watershed to its WQMA. The ranks are shown as the last column in Table 6.4. Again, these ranks are based only on the qualitative criteria discussed.

A RANKING OF WATERSHEDS FOR IMPLEMENTATION

Watershed 7, Mallets Bay, and watershed 18, Shelburne Pond, have significantly lower agricultural phosphorus loadings than the balance of the watersheds. Because they are adjacent and hydrologically related to watersheds 8 and 9, respectively, for efficiencies in agricultural NPS management, watersheds 7 and 8 will be combined as will watersheds 9 and 18 in further prioritization analyses.

With the quantitative rankings of WQMA's in Table 6.3 and of watersheds within the WQMAs in Table 6.4, an overall numerical ranking of the watersheds has been made as provided in Table 6.5. For each watershed the rank of its WQMA from Table 6.3 is summed with its rank from Table 6.4. This score is then compared to that of the other watersheds and is ranked. In the case of tied scores, the watershed with a lower WQMA rank precedes. Based on these results, the watersheds are rearrayed by rank.

It is interesting to note from the results of Table 6.5 that watersheds with treatment already underway or under steps for treatment program authorization (which have occurred since this study started) all fall within the top third of the rankings. These watersheds are the Dead Creek-Otter Creek, authorized for installation under PL83-566, September 1981; the Lower Winooski River (including Shelburne Pond), and the Lemon Fair River, each authorized for planning in August 1982; and Harvey's Lake, which had been in final phases for Clean Lakes assistance if funds had become available.

To provide for special considerations not evaluated in Table 6.5, the watersheds have been further categorized into high, medium and low

Table 6.1 Ranking of Agricultural Watersheds Within WQMA's for NPS Pollution Management

Lake	WQMA	Watershed		Annual Total Phosphorus in Pounds per Year: Total	Point Source	Non-Point Source	Agr'l Source	% of WQMA	WQMA Rank	Distance-Miles WQMA to WQMA Watershed Outlet	Rank	Control cost-Dollars per lb. of Agr'l P	WQMA Rank	Rank Among 19	Sum of WQMA Ranks	Overall Rank in WQMA 1/
Champlain																
	Central Main Lake			371,280	243,850	127,430	56,110	15.1								
		Lower Winooski	(9)	104,525	84,935	19,590	8,160	2.2	(2)	0	(-)	97.83	(2)	10	(4)	(2)
		Direct Drainage	(10)	30,700	-	30,700	13,870	3.7	(1)	0	(-)	32.64	(1)	4	(2)	(1)
	Malletts Bay			102,060	30,280	71,780	53,455	52.4								
		Malletts Bay	(7)	3,830	-	3,830	1,275	1.2	(2)	0	(1)	334.88	(2)	18	(5)	(2)
		Browns River	(8)	10,380	-	10,380	8,130	8.0	(1)	16	(2)	74.55	(1)	8	(4)	(1)
	Missisquoi Bay			277,650	80,190	197,460	177,460	63.9								
		Trout River	(3)	5,010	-	5,010	3,320	1.2	(4)	35	(4)	102.77	(4)	12	(12)	(4)
		Tyler River	(4)	39,000	25,250	13,750	13,110	4.7	(2)	28	(3)	81.20	(2)	9	(7)	(2)
		Black Creek	(6)	8,620	-	8,620	6,570	2.4	(3)	22	(2)	98.23	(3)	11	(8)	(3)
		Rock River-Pike Creek	(5)	45,850	14,890	30,960	29,880	10.8	(1)	0	(1)	38.63	(1)	5	(3)	(1)
	South Lake			82,310	16,270	66,040	56,750	68.9								
		Mettawee River	(17)	17,290	4,390	12,900	11,030	13.4	(2)	16	(2)	138.16	(2)	16	(6)	(2)
		Direct Drainage	(10)	19,240	400	18,840	16,270	19.8	(1)	0	(1)	32.64	(1)	4	(3)	(1)
	South Main Lake			439,430	90,860	348,570	294,730	67.1								
		Lewis Creek	(11)	17,710	-	17,710	16,510	3.8	(5)	0	(-)	52.87	(4)	6	(9)	(5)
		Little Otter	(12)	42,920	-	42,920	42,080	9.6	(3)	0	(-)	55.08	(5)	7	(8)	(4)
		New Haven	(13)	10,400	-	10,400	6,410	1.5	(7)	22	(2)	116.23	(6)	13	(15)	(6)
		Lower Otter-Dead Creeks	(14)	66,030	6,000	60,030	57,260	13.0	(2)	0	(-)	26.81	(1)	1	(3)	(1)
		Lemon Fair	(15)	67,150	-	67,150	64,760	14.7	(1)	16	(1)	28.69	(2)	2	(4)	(2)
		Middle Otter	(16)	31,390	12,340	19,050	15,390	3.5	(6)	27	(3)	124.16	(7)	15	(16)	(7)
		Direct Drainage	(10)	47,900	-	47,900	25,110	5.7	(4)	0	(-)	32.64	(3)	4	(7)	(3)
Memphremagog																
	Newport Bay & Vermont Portion of South Basin			58,730	11,990	46,740	33,960	57.8								
		Clyde River	(1)	11,510	-	11,510	7,735	13.2	(2)	0	(-)	121.66	(1)	14	(3)	(2)
		Barton River	(2)	12,740	-	12,740	9,720	16.5	(1)	0	(-)	177.01	(2)	16	(3)	(1)
Shelburne																
	Entirety	Shelburne Pond	(18)	1,220	-	1,220	990	81.1	(1)	0	(-)	182.84	(-)	17	(1)	(1)
Harveys																
	Entirety	Harveys Lake	(19)	3,860	-	3,860	3,440	89.0	(1)	0	(-)	29.66	(-)	3	(1)	(1)

1/ In cases of tie the watershed having the higher agricultural source P is chosen.

Table 6.5 Quantitative Ranking of Agricultural Watersheds for NPS Treatment

No.	Watershed	Scores: WQMA Table 6.1	Scores: Watershed Table 6.2	Sum	Rank 1/		Watershed Rearray by Rank	Steps Toward Funding Authorized?
1	Clyde River	5	2	7	8	10	Lower Lake Champlain	No
2	Barton River	5	1	6	7	9 & 18	Lower Winooski River & Shelburne Pond	Yes
3	Trout River	6	4	10	16	7 & 8	Malletts Bay & Browns River	No
4	Tyler Branch	6	2	8	11	19	Harvey's Lake	Yes
5	Rock River & Pike Creek	6	1	7	9	14	Dead Creek-Otter Creek	Yes
6	Black Creek	6	3	9	13	15	Lemon Fair River	Yes
7 & 8	Malletts Bay & Browns River	2	1	3	3	2	Barton River	No
9 & 18	Lower Winooski River & Shelburne Pond	1	2	3	2	1	Clyde River	No
10	Lower Lake Champlain	1	1	2	1	5	Rock River & Pike Creek	No
11	Lewis Creek	4	5	9	12	12	Little Otter Creek	No
12	Little Otter Creek	4	4	8	10	4	Tyler Branch	No
13	New Haven River	4	6	10	15	11	Lewis Creek	No
14	Dead Creek-Otter Creek	4	1	5	5	6	Black Creek	No
15	Lemon Fair River	4	2	6	6	17	Mettawee River	No
16	Mid Otter Creek	4	7	11	17	13	New Haven River	No
17	Mettawee River	7	2	9	14	3	Trout River	No
19	Harvey Lake	3	1	4	4	16	Mid Otter Creek	No

1/ In cases of ties the watershed with lower WQMA rank precedes.

priority for program assistance. The sequence of watersheds of Table 6.5, less those with steps towards implementation already underway, are partitioned into the three categories as provided in Table 6.6. Known special considerations for each watershed are listed. This arrangement provides an opportunity to consider other watershed concerns when choosing a watershed for program assistance.

Future changes within the watersheds may affect their order of priority for treatment. It is recommended that Table 6.6 be reviewed at least annually with the Vermont Agency of Environmental Conservation and others to keep it current.

Table 6.6. Grouping Suggested for Providing Assistance to the Watersheds

High Priority	Medium Priority	Low Priority
Lower Lake Champlain (10)	Little Otter Creek (12)	Metawee River (17)
Mallets Bay and Browns River (7 & 8)	Tyler Branch (4)	New Haven River (13)
Barton River (2)	Lewis Creek (11)	Trout River (3)
Clyde River (1)	Black Creek (6)	Mid Otter Creek (16)
Rock River and Pike Creek (5)		
Harvey's Lake (19)		

Special Considerations:

Watershed	Consideration
1	Lakes Derby, Salem, Seymour and Echo are interior water bodies.
2	Lakes Crystal, Willoughby, et al. are interior water bodies.
3	
4	
5	Flows in and out of Quebec -- will require international cooperation for best management.
6	
7	Rapidly urbanizing area.
8	
9	
10	
11	Lakes Cedar and Winona are interior.
12	
13	
16	
17	NY Dept. of Environmental Conservation concerned about thermal pollution.

WATER QUALITY MANAGEMENT AREA RESPONSE

Suitable models for determining the trophic state response of various WQMA's in Lake Champlain and Shelburne Pond are not available. Development of such models is beyond the scope of this study. The Vermont Department of Water Resources is currently preparing a model for Harvey's Lake to simulate response to various conditions in the drainage basin. The Vermont Department of Water Resources has also recently performed an analysis of Lake Memphremagog response to point and nonpoint source phosphorus controls. The results of this analysis illustrate how Lake Memphremagog would likely respond to the Suggested Plan. The results of this analysis should not be extrapolated to other WQMA's of the study. But they do show a positive response to agricultural nonpoint source phosphorus reduction to the Lake Memphremagog WQMA under conditions where a significant point source of phosphorus also exists.

As discussed in Chapter 3, Lake Memphremagog receives about 84 percent of its total phosphorus load from Vermont sources. Virtually all of this load enters the Lake at Newport Bay (see Map 3.7). These Vermont sources are estimated at 11,990 pounds annually from the Newport Wastewater Treatment Plan (WWTP) and 46,740 pounds annually from nonpoint sources. In 1984 when the Newport WWTP goes to tertiary treatment, its load will be reduced to an estimated 2,430 pounds annually.

The Vermont Department of Water Resources has modeled various scenarios of total phosphorus inputs to the Lake. The scenarios and the associated predicted total phosphorus and chlorophyll concentrations in Newport Bay and South Bay are shown in Table 6.7.

Figures 6.1 and 6.2 graphically illustrate the results of modeling these scenarios for two segments of the Vermont portion of the Lake, Newport Bay and South Basin. Scenario 1, the existing condition, shows Newport Bay to be highly eutrophic and South Basin near eutrophic.

Little trophic state change in these waters is noted by introducing nonpoint source controls on the Black River in scenario 2. The Black River Watershed flanks the Barton River Watershed and was authorized for installation of a PL 83-566 watershed protection project in September 1982.

By controlling all of the principal nonpoint source phosphorus under scenario 3, Newport Bay would remain slightly eutrophic and South Basin would be mildly mesotrophic. Introducing tertiary treatment at the Newport WWTP, scenario 4, with only ongoing nonpoint source phosphorus controls, would have essentially the same effect as scenario 3. Tertiary treatment at the Newport Wastewater Treatment Plant with the PL 83-566 project in the Black River Watershed, scenario 5, renders Newport Bay bordering eutrophic and South Basin mildly mesotrophic. Scenario 6, controlling all sources, provides for a mesotrophic Newport Bay and oligotrophic South Basin.

Table 6.7 Model Results of Six Different Phosphorus Loading Scenarios - Vermont Portion of Lake Memphremagog 1/

		Nonpoint Source Condition			Predicted Total P (mg/m^3)		Predicted Chl (mg/m^3)
Scenario	Point Source Condition 2/	Black R.	Clyde R.	Barton R.	Newport Bay	South Basin	South Basin
1	Existing	Ongoing	Ongoing	Ongoing	30	18	7.0
2	Existing	W/566 Project	Ongoing	Ongoing	27	17	6.7
3	Existing	W/566 Project	Suggested Plan		21	13	5.6
4	1 mg/l	Ongoing	Ongoing	Ongoing	22	14	5.9
5	1 mg/l	W/566 Project	Ongoing	Ongoing	20	12	5.4
6	1 mg/l	W/566 Project	Suggested Plan		14	8.5	4.4

1/ Smeltzer, June 1982

2/ Wastewater Treatment Plant at Newport

Fig. 6.1 Predicted Trophic State of Newport Bay (Lake Memphremagog)

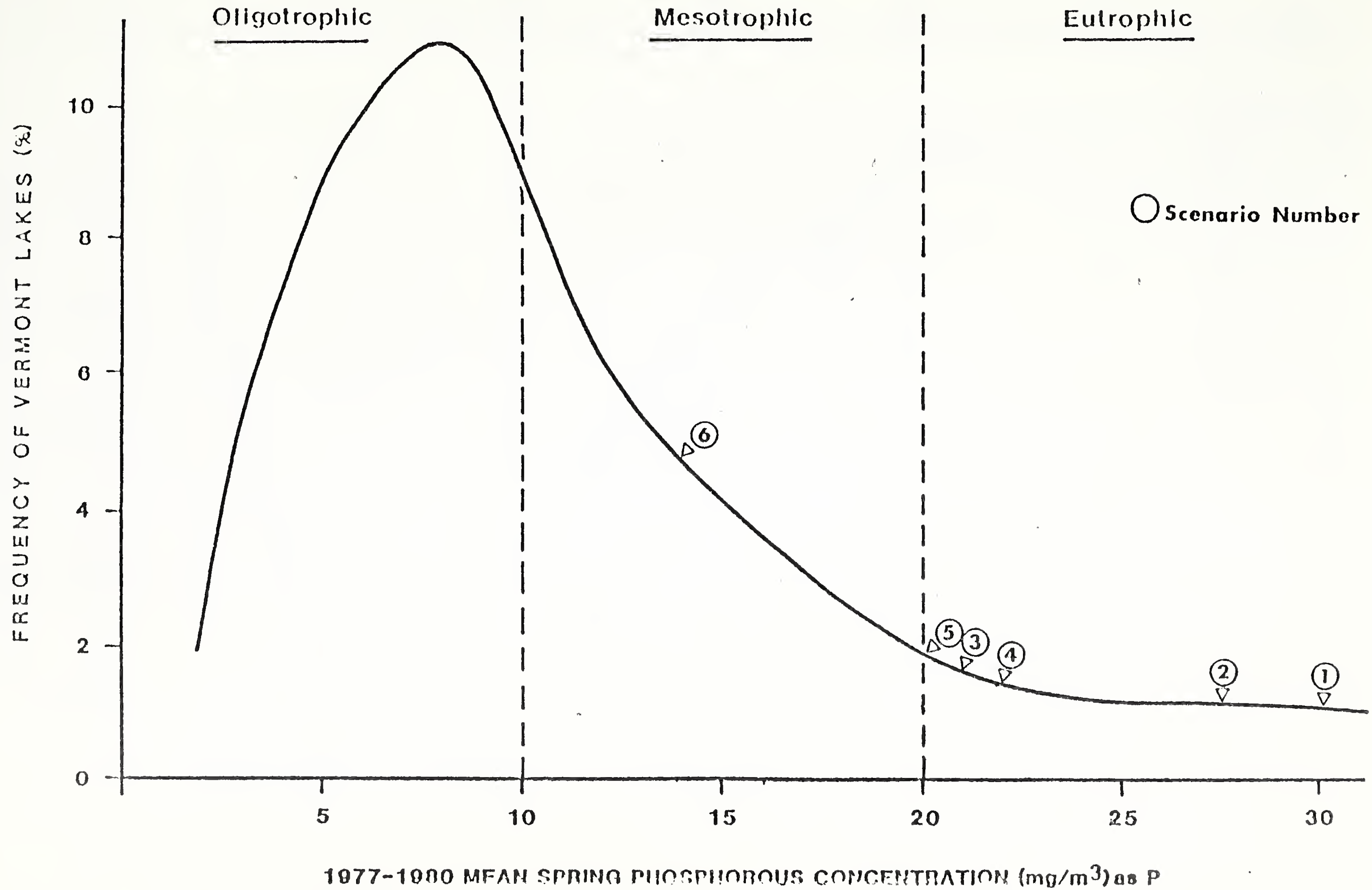
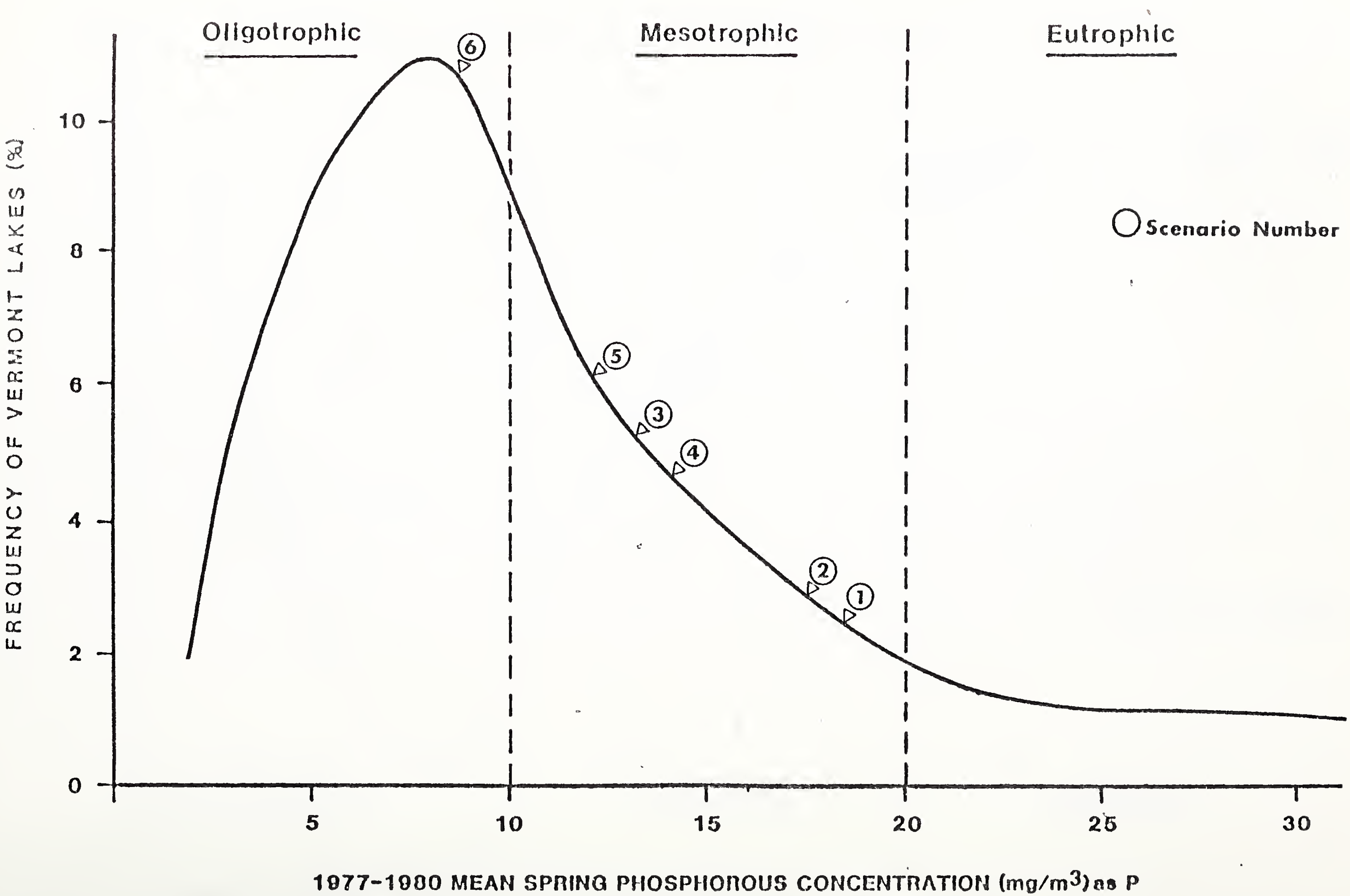


Fig. 6.2 Predicted Trophic State of South Basin (Lake Memphremagog)



In summary, reductions in phosphorus loading are needed for both the point and nonpoint sources to bring the trophic state of Newport Bay into the mesotrophic range and South Basin into the oligotrophic range. Less control will likely result in a eutrophic condition remaining in heavily used Newport Bay. The Suggested Plan is warranted here to complement other phosphorus control efforts in achieving a desirable trophic state in Lake Memphremagog.

CHAPTER 7

GETTING ON WITH THE JOB

IMPLEMENTATION PROGRAMS AVAILABLE

As revealed in Chapters 5 and 6, accelerated watershed protection is needed to implement a desirable level of best management practices in each of the watersheds for the protection of the various WQMA's, reduction of excessive soil loss and efficient utilization of agricultural wastes.

A number of programs provide for accelerated implementation of best management practices. These are administered by USDA, USEPA and the Vermont Agency of Environmental Conservation. These are listed in Table 7.1. The future of these programs is not predictable. For the purposes of this study, it is assumed that future program assistance will continue at the rate it has in the past five years.

SCHEDULING THE WORK

An implementation schedule is provided in Table 7.2 as a guide towards developing an action plan for controlling agricultural runoff from the study watersheds. The schedule shows watersheds arrayed in order of the ranking established in Chapter 6. One should not interpret this sequence as priorities established by the Vermont Agency of Environmental Conservation. There may be other considerations necessitating a rearrangement of watersheds in the schedule.

Programs under which watershed protection will be implemented are not identified in the schedule. Progress is portrayed based on activities over the past five years of programs identified in Table 7.1. It is also assumed that no large increases in personnel services will be available from the various agencies to accelerate program assistance beyond current levels. In the past five years, the following progress has been made:

Project	Number	Watershed Equivalent
ACP Special Projects	35	2
Rural Clean Water Project	1	1
Cons. Operations Targeted Area	0	0
PL 83-566	3	3
RC&D	2	2
Section 314	0	0
Sum	41	8
Average		1.6

The schedule is, therefore, based on servicing three new watersheds every two years. The project installation period is estimated as a minimum of four years or one year per $150,000 of installation cost, whichever is greater, not to exceed ten years.

Table 7.1. Programs Providing Accelerated Assistance Towards Implementation of Best Management Practices in Specific Geographic Areas

Agency	Program	Program Features
U.S. Department of Agriculture -- Agricultural Stabilization and Conservation Service	Agricultural Conservation Program--Special Projects	Accelerated financial and technical assistance for implementation of appropriate best management practices (BMPs) in targeted areas. Addresses problem(s) identified in application. Application for special projects is initiated by the ASC County Committee, filed with the Administrator, ASCS, and are selected and funded from a portion of each year's ACP national budget targeted for special projects.
	Rural Clean Water Program	Accelerated financial and technical assistance for implementation of water quality improvement and protection measures in approved project areas. Cost sharing assistance is provided through RCWP contracts (3 to 10 years duration) to install BMP's for control of critical water quality problem sources. Generally a project area lies within a single watershed having a serious water quality problem and/or problem sources. Application is limited by the ASC County Committee and is selected at the national level for funding. Funding is provided at the authorization of the project.

Table 7.1. (cont.)

Agency	Program	Program Features
-- Soil Conservation Service	Conservation Operations Program Targeted Area	Accelerated technical assistance to targeted areas for addressing high priority problems of national and regional concern. Funded from reserving a portion of the national conservation operations program's budget for targeted areas. Initiated through application by local and state governments. Targeted areas selected at the national level.
	Public Law 83-566, Watershed Protection and Flood Prevention Act	Provides accelerated technical and financial assistance for implementation of conservation land treatment measures as a needed complement to the ongoing programs for achieving measurable effects in: (a) reducing floodwater damages; (b) reducing erosion damages; (c) reducing sedimentation damages; (d) providing water conservation; (e) enhancing fish and wildlife habitat (f) improving water quality; (g) producing other environmental quality benefits. Watershed areas of 250,000 acres or less, having one or more of the above needs in which the overall benefits exceed the costs, are eligible.

Table 7.1. (cont.)

Agency	Program	Program Features
	Public Law 83-566, Watershed Protection and Flood Prevention Act (cont.)	Applications for watershed projects are initiated by Natural Resource Conservation Districts and other local and state entities, submitted and prioritized through the Vermont Agency of Environmental Conservation, and referred to the Soil Conservation Service for watershed plan development and authorization. Project duration is normally from 7 to 10 years. Land treatment measures are applied through long-term contracts (3 to 10 years) with landowners or operators. Funding is subject to annual appropriations of Congress.
	Resource Conservation and Development	Provides accelerated technical and financial assistance for implementation of soil and water conservation management for agriculture-related pollutant control. To be eligible for treatment, the pollutants must be adversely affecting a community and the general public. Local governments apply for assistance through the RC&D area council. Funding is based on an approved RC&D measure plan and is subject to annual appropriations of Congress. Long-term contracts (3 to 10 years) with landowners and operators provide the medium for implementation.

Table 7.1. (cont.)

Agency	Program	Program Features
U.S. Environmental Protection Agency	Section 314, Clean Lakes Program -- Phase 2	Cooperative Agreement with states to restore publicly owned freshwater lakes through pollutant control and in lake efforts. Applications must be filed by states with EPA. Cost sharing of 50 percent available as federal share for pollution control measures. Project length not to exceed 4 years.

Table 7.2 Suggested Implementation Schedule for Watershed Protection

No.	Watershed	Application Date	Plan of Work	Planning Authorized	Operations Authorized	Installation Complete	Installation Cost: Construction	Installation Cost: Technical	Installation Cost: Financial Assistance	Remarks
14	Dead Creek-Otter Creek	1979	1979	1979	1981	1988	1,472,200	201,100	777,600	
9-18	Lower Winooski River	1980	1981	1982	1983	1987	329,200	85,900	183,100	Authorized under PL83-566
15	Lemon Fair River	1980	1981	1982	1984	1991	914,500	129,400	484,000	Authorized under PL83-566
19	Harvey's Lake	1983	1983	1984	1984	1985	42,200	10,000	24,200	VT Agency of Environmental Conservation has developed NPS control plans
5	Rock River-Pike River	1983	1983	1984	1985	1990	388,000	61,100	202,000	
2	Barton River	1983	1984	1985	1985	1992	563,000	105,200	296,000	
10	Lower Lake Champlain	1984	1984	1985	1986	1993	579,285	89,540	311,400	
7-8	Malletts Bay & Browns River	1985	1985	1986	1987	1991	378,500	77,400	204,800	
1	Clyde River	1985	1985	1986	1987	1991	383,100	81,500	210,200	
4	Tyler Branch	1986	1986	1987	1988	1993	386,700	57,800	198,000	
12	Little Otter Creek	1987	1987	1988	1989	1996	967,000	141,500	537,000	
11	Lewis Creek	1987	1987	1988	1989	1992	229,200	45,000	124,400	
6	Black Creek	1988	1988	1989	1990	1992	183,600	48,300	104,200	
17	Mettawee River	1989	1989	1990	1991	1996	636,100	106,300	329,600	
13	New Haven River	1989	1989	1990	1991	1994	370,400	74,900	199,200	
3	Trout River	1990	1990	1991	1992	1994	147,600	40,400	83,800	
16	Mid Otter Creek	1991	1991	1992	1993	2000	945,500	162,600	492,400	

IMPLEMENTATION CONSIDERATIONS

In developing management plans for watersheds covered under this study planners should recognize the following.

- Values provided from this study are likely not refined enough for use in project plans.
- Landowner/operator participation rates should be carefully considered. This study assumed 100 percent participation of the problem area farms. This level is rarely attained.
- Proximity of problem nonpoint sources to watershed outlets and other intra-watershed off-farm factors which govern the quantity of pollutants reaching watershed outlets have not been considered in the study.
- Variable cost share rates for BMP's should be considered in terms of desired participation from landowners of problem areas, impacts on net farm income, and inequities if varied by farm size. Loans and other incentives should be considered.
- Offsite effects from project actions need further evaluation, particularly monetary, social and water quality factors.
- Water bodies contained within some watersheds also need evaluation for effects of project action.
- This study has evaluated nutrient and sediment pollution from nonpoint sources. Bacteriological contamination is also a problem in some areas.
- This study provides estimates of and suggestions for control of sheet and rill erosion. Gully, streambank and ephemeral erosion, while not as critical, also should be evaluated in developing project plans.

The study's technical reports should serve as a foundation for project planning.

Quantification of Resources and Problems in Agricultural Runoff Study Watersheds will be useful in developing watershed applications and preauthorization planning reports. Computational Methods for Assessing Phosphorus Losses in the Vermont Agricultural Runoff Study provides methods and models which may be employed with appropriate analyses. Phosphorus Reduction and Farm Income: Modeling Efficient Responses to Phosphorus Loading Constraints on Vermont Dairy Farms provides extensive evaluations of trade-offs between phosphorus reduction (including erosion control and animal waste management) and farm income. Project economic evaluations will be facilitated through its use. Erosion and Sediment Production from Logging Roads in Vermont scopes forest land harvest access erosion problems in the various watersheds; while Proposed Private Road System in the Browns River Watershed, Vermont explores optimum harvest road access routes in a representative study watershed which may well have conceptual application in other watersheds.

GLOSSARY

GLOSSARY

Adsorbed phosphorus	Phosphorus that is bound to soil particles.
Animal wastes	Byproducts of the farm enterprise that are associated with animal management. They include manure and all waste material associated with the milking operation.
Available phosphorus	Phosphorus that is available as a nutrient for aquatic plant growth. Assumed in this study to be all of the dissolved phosphorus plus 20 percent of the adsorbed phosphorus.
Best management practice	A practice or combination of practices that are determined by a state or designated areawide planning agency to be the most effective and practicable means of controlling the amount of pollution from nonpoint sources to a level compatible with water quality goals.
Bioavailable phosphorus	See available phosphorus.
Conservation practice	A measure commonly used to meet a specific need in planning and carrying out soil and water conservation programs for which standards and specifications have been developed.

Conservation tillage	Method of planting crops while leaving a high degree of residue on the field either by planting the seed in a chiseled slit or by restricting tillage to leave residue from previous year's crop on the field surface.
Delivery ratio	The ratio of sediment yield to gross erosion expressed in percent.
Dissolved phosphorus	Phosphorus that is in solution in the water.
Diversion	A channel constructed across the slope of a field to intercept the flow of water and divert it to a stable outlet.
Ecosystem	A community, including all the component organisms, together with the environment, forming an interacting system.
Enrichment factor	A multiplier used to increase the adsorbed phosphorus concentration in sediment. It compensates for the fact that sediment is made up of a finer fraction of soil particles with more surface area and a corresponding greater proportion of the adsorbed phosphorus than the original soil. 1.5 was used as the enrichment factor in this study.

Epilimnion	The water mass extending from the surface to the thermocline in a stratified body of water; the epilomnion is less dense than the lower water masses, is wind circulated and has about the same temperature throughout. See hypolimnion.
Erosion	Detachment and movement of soil or rock fragments by water, wind, ice, or gravity.
Eutrophication	A means of aging of lakes whereby aquatic plants are abundant and waters are deficient in oxygen. The process is usually accelerated by enrichment of waters with surface runoff containing nitrogen and phosphorus.
Lacustrine soils	A popular (not technical) term for soils which were formed in sediments that accumulated at the bottom of former lakes. The soils formed after the sediments emerged above water level.
Nonpoint pollution	Pollution whose sources cannot be pinpointed; can best be controlled by proper soil, water, and land management practices.
Orthophosphorus	Phosphorus in aqueous solution in the form of H PO or H PO.

P	Phosphorus.
Particulate phosphorus	See adsorbed phosphorus.
PHSRED	Computer program which computes the phosphorus, erosion, and sediment yields from cropland under varying cropping and management practices.
Sediment	Soil material, both mineral and organic, that is in suspension, is being transported, or has been moved from its site of origin by air, water, gravity, or ice and has come to rest on the earth's surface either above or below sea level.
Sediment delivery rato	See delivery ratio.
Sub-basin	The drainage area for a water quality management area.
Total phosphorus	The sum of the dissolved phosphorus and adsorbed phosphorus.
Trophic condition	The stage that a water body occupies in the eutrophication process.
T-value	The maximum rate at which a soil can erode and still sustain crop production in an economic fashion.

Water quality management area	A subdivision of Lake Champlain or Lake Memphremagog which is treated as a distinct unit for study and management.
Watershed	All land and water within the confines of a drainage divide or a water problem area.

REFERENCES

REFERENCES

Bevins, M.I., T.L. Brown, G.L. Cole, K.J. Hock, M.W. Kottke, W.F. Lapage, R.W. Stammer, and D.J. Stynes.

Changing Patterns of Outdoor Recreation Participation in Northeastern United States.

Bulletin 427, NE Regional Research Project NE-100, Agr. Exp. Station, University of Delaware, April 1979.

Bogdan, K.G.

Estimates of the Annual Loading of Total Phosphorus to Lake Champlain. September 1978.

Bureau of Economic Analysis.

Industry-Specific Gross Output Demand Multipliers for BEA Economic Areas.

U.S. Department of Commerce, Washington, D.C., January 1979.

Carlson, R.E., J. Kalff, and W.C. Leggett.

The Phosphorus and Nitrogen Budgets of Lake Memphremagog (Quebec-Vermont); With a Predictive Model of Its Nutrient Concentration Following Sewage Removal.

Inland Waters Directorate, Fisheries and Environment, Canada, March 1979.

Cassell, E. Alan, and Donald W. Meals, Jr.

Laplatte River Watershed, Water Quality Monitoring and Analysis Program, Program Report No. 3.

Program Achievement Report, 1981.

Draper, D.W., J.B. Robinson, and D.R. Coote.

Estimation and Management of the Contribution by Manure from Livestock in the Ontario Great Lakes Basin to the Phosphorus Loading of the Great Lakes in Best Management Practices for Agriculture and Silviculture.

Proceedings of the 1978 Cornell Agricultural Waste Management Conference, Ann Arbor Science Publishers, Inc., 1979.

Esser, Anthony J.

"Barnyard Package is West Branch Exclusive".

Soil, Water, People. Delaware County Soil and Water Conservation District, January 1982.

Forest Service.

Erosion and Sediment Production from Logging Roads in Vermont.

Vermont Ag Runoff Technical Report No. 3, Forest Service, USDA, Burlington, Vermont, September 1982.

Forest Service.

Proposed Private Road Systems in the Brown's River Watershed.

Vermont Ag Runoff Technical Report No. 4, Forest Service, USDA, Burlington, Vermont, Spetember 1982.

Gilbert, A.H.

Unpublished tables provided in personal correspondence.

September 1981.

Gilbert, A.H. and L. Winant.

The Economic Value of Water-Oriented Outdoor Recreation on Lake Champlain.

Lake Champlain Level B Study Technical Research Report LCBS-04, December 1977.

Godfrey, Raymond G.

Vermont's Primary Agricultural Soils.

Unpublished paper, Soil Conservation Service, Burlington, Vermont, 1982.

Heimlich, R.E.

Phosphorus Reduction and Farm Income: Modeling Efficient Responses to Phosphorus Loading Constraints on Vermont Dairy Farms.

Vermont Ag Runoff Technical Report No. 2, Economic Research Service, USDA, Burlington, Vermont, May 1982.

Henson, E.B. and G.L. Gruendling.

The Trophic Status and Phosphorus Loadings of Lake Champlain.

U.S.E.P.A., Report No. 600/3-77-106, 1977.

Henson, E.B. and M. Potash.

Material Budget of Lake Champlain.

USDI, PB-254-562, 1976.

Horwitz, Elinor L.

Our National Lakes.

U.S.E.P.A., 1980.

Lake, James, NACD, United States Environmental Protection Agency.

Environmental Impact of Land Use on Water Quality, Final Report on the Black Creek Project.

Report No. 905/9-77-0078, October 1977.

Lee, G.F., et al.

"Availability of Phosphorus to Phytoplankton and Its Implications for Phosphorus Management Strategies."

From Phosphorus Management Strategies for Lakes, Loehr, et al., Cornell University and the International Joint Commission, 1980.

Loehr, Raymond C.

"Characteristics and Comparative Magnitudes of Non-Point Sources."

Water Pollution Control Federation Journal, Vol. 46, No. 8, August 1974.

Meeks, Harold A.

The Geographic Regions of Vermont: A Study in Maps.

Geography Publications at Dartmouth, No. 10, Special Bicentennial Publication, 1975.

Moore, I.C., E.W. Madison, and R.R. Schneider.

Estimating Phosphorus Loading from Livestock Wastes: Some Wisconsin Results.

Proceedings of the 1978 Cornell Agricultural Waste Management Conference, Ann Arbor Science Publishers, Inc., 1979.

NERBC.

Lake Memphremagog - St. Francis River Basin Overview. New England River Basin Commission, Burlington, Vermont, May 1981.

NERBC.

Shaping the Future of Lake Champlain. Final Report of the Lake Champlain Basin Study, New England River Basins Commission, Burlington, Vermont, September 1979.

New England Crop and Livestock Reporting Service.

Vermont Crop Summary, 1979 Crop Year. Statistical Reporting Service, Concord, New Hampshire, February 1980.

Smeltzer, E.

Modeling Analysis of Lake Memphremagog to Assess the Effectiveness of Both Point and Non-Point Source Phosphorus Controls in Improving Lake Water Quality. Vermont Department of Water Resources and Environmental Engineering, June 1982.

Soil Conservation Service.

Computational Methods for Assessing Phosphorus Losses in the Vermont Agricultural Runoff Study. Vermont Ag Runoff Technical Report No. 1, Soil Conservation Service, USDA, Burlington, Vermont, May 1982.

Soil Conservation Service.

Quantification of Resources and Problems in Agricultural Runoff Study Watersheds.

Technical Report of the Agricultural Runoff in Selected Vermont Watersheds Study, Soil Conservation Service, USDA, Burlington, Vermont, November 1982.